SEWAGE DISPOSAL

IN THE

TROPICS

BY

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TO

M. I. C.

PREFACE.

THE first systematic study of the biological process of Sewage Disposal in the Tropics was commenced by Dr. Fowler and myself in January 1906. Previous to this time, a certain amount of work had been done on the sterilization of tank effluent and on such practical matters as the best flushing apparatus and the most advantageous arrangement of the latrine; but nothing of the nature of a programme of chemical research was undertaken until Dr. Fowler visited Bengal. To him is due the credit of starting and systematising the research work. The report on "Septic Tanks in Bengal" published by him covered a great deal of ground, but it was not to be expected that in three months all the problems connected with this complex subject could be fully worked out. His work has been continued on since his departure, and it now appears to be desirable to publish the results in a form that will be most useful to Sanitary Officers, District Engineers, and all who are interested in the improvement of sanitary conditions in the East. It is not maintained that any finality has been reached in this subject; much work remains to be done; many problems are at present being worked out in our laboratory, the results of which will be published later on.

Our thanks are due to Captain McCay, I.M.S., Professor of Physiology, Medical College, for assisting in part of the chemical work, to S. H. Ashworth, Esq., Manager, Gouripur Jute Mill, to J. Thomson, Esq.,

Manager, Tittagurh Jute Mill, to the Manager of the Shamnuggur Jute Mill, and many others connected with mills who have assisted us in carrying out experiments on their installations. We also wish to express our gratitude to Captain E. D. W. Greig, I.M.S., and to Babu Bidhu Bhusan Sinha Roy for kindly revising the proofs.

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takes place at *A*. Fig. II (*k*) works extremely well in jails where the prisoners are under control and can be

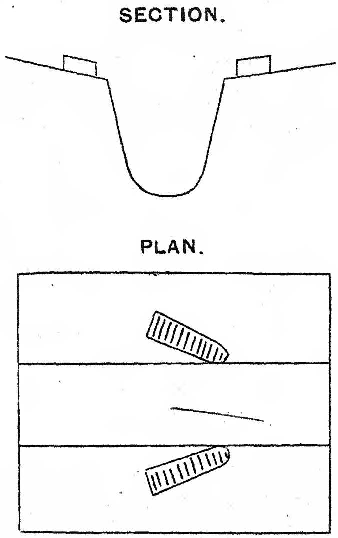


FIG. II (*k*).—This is a fair type; if foot-rests are not provided at all it still works pretty well.

made to use the latrine the right way round. They are not popular with the ordinary coolies, and it is practically impossible to make the mill people use these as they are intended. They do however very much better as latrines for private houses.

The advantages of the trough system of latrine over the pan system are: (1) that it is very much cheaper to construct than the pan closet; (2) that no mechanically-actuated flushes are necessary; this item also considerably reduces the cost; (3) that there is nothing that can possibly get out of order in the latrine.

The disadvantages are almost entirely dependent on faulty design. Even the objection raised to the automatic flush, on the ground that it splashes the user, can be easily overcome by seats of satisfactory design. It will be observed that the advantages of the trough variety greatly preponderate over the disadvantages.

We now proceed with the subject of flushing arrangements. Before doing so, it may be well to point out, for the benefit of those who are not conversant with the customs of the East, that no caste man will have anything to do with a latrine when it has once been used, on the ground that it constitutes a pollution. Consequently any apparatus, which is liable to get out of order, should be avoided. Only sweeper *mistries* and Christians will undertake the repairs; both are very difficult to obtain. It follows, therefore, from these remarks that all mechanical apparatus, such as actuated flushes, are a source of considerable worry and annoyance to the owner of the latrine, because of the difficulty of getting repairs done when they are out of order. These are the serious disadvantages to the more scientific way of flushing a latrine. It is obvious that after a latrine has been used, it should be flushed *at once*, and the best method of doing so, is the way in which it is done in all civilised countries, namely, by the user actuating the flush himself by means of a handle. In practice this arrangement cannot be installed in the East; firstly, people of the nature of mill coolies will steal the handles, chains, nuts, bolts and anything which has a small value in the bazaar; secondly, they object to touching the handle, because the sweeper touches it, and this alone constitutes pollution. Consequently any mechanism which actuates the flush must be done either by an arrangement of pedals, or by opening and shutting of

the door. As regards this latter, we have not yet seen any satisfactory design of a door-actuated flush, and another objection is that doors are not fitted to most of the latrines in this country. A very fairly satisfactory pedal arrangement has been constructed. It usually answers very well when new, but the usage that it receives at the hands of mill coolies, generally succeeds in breaking it sooner or later. A very simple and accessible flush arrangement actuated by pedals, *vide* figure II (*j*), has been designed recently, and has been tried in several of the mills. It is certainly satisfactory in action, does not leak, and all working parts are easy of access and easy of repair. Unfortunately it has not been in work for many

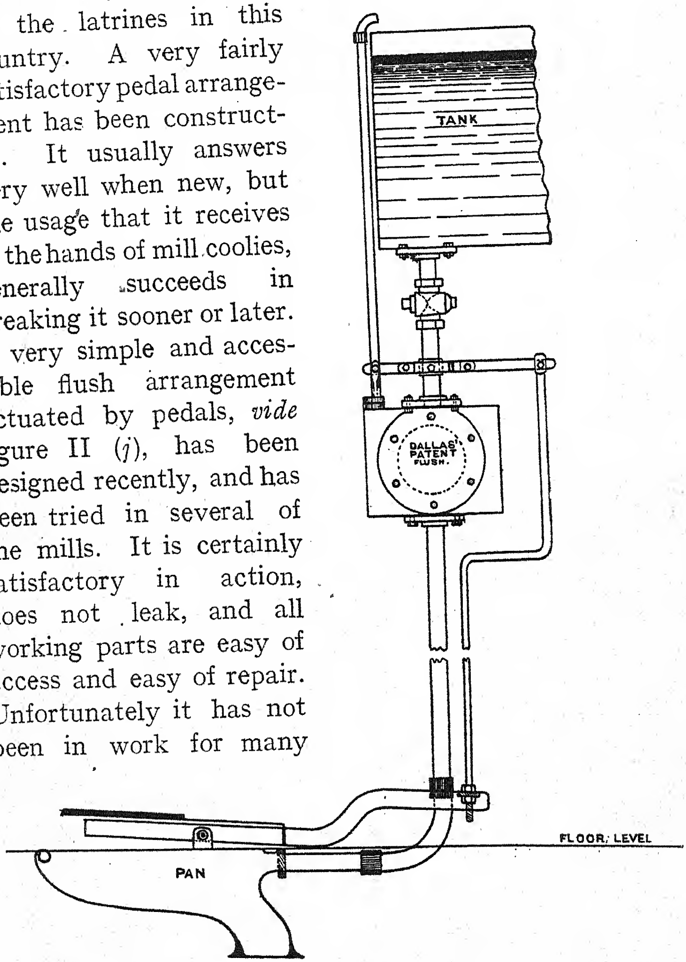


FIG. II (*j*). Pedal-actuated flush.

years, so the life of the apparatus cannot be estimated at present. The cost of this flush is Rs. 70 in Calcutta; they can be purchased from Messrs. Bird & Co., who have bought the patent rights. There were several other pedal-actuated flushes all of which have disappeared, principally from the fact that they require endless attention and their life is extremely short.

Another disadvantage of all these mechanically acting flushes is on the ground of expense; they add very considerably to the estimates for a large latrine.

(*iii*) *Automatic acting Flushes.*

(*A*) *The tip tank*—

The tip tank is a method of flushing which is not at all satisfactory in the East. It is particularly impossible to get an alloy of metal that will stand for any length of time the atmosphere of the latrine. Further, tip tanks wear out and become unsatisfactory in direct proportion to their size. The usual capacity of the tank is about 3 to 4 gallons and when new they act fairly satisfactorily; but in the East rusting of the bearing takes place, and they very soon begin to work irregularly. In one instance in Bengal a mill-owner made a 40-gallon tip tank. The mechanism was not very satisfactory, the weight on the bearings being much too great.

(*B*) *Syphon flushes*—

There appears to be a sort of idea abroad that any mechanic, builder or contractor is competent to design a syphon flush—a greater mistake never existed—as those who have tried the amateur's flush know to their cost. Syphon flushes designed by Messrs. Adams, Ham Baker and firms of repute are very satisfactory and give no trouble whatever. The flush should discharge into

one end of the trough, so that the whole length is well washed down. For a large latrine 40—60 gallons is necessary to force all the matter into the tank.

The disadvantages of automatic acting flushes are—

(1) theoretically the night-soil is exposed for a certain length of time to the atmosphere. This, however, is not a real objection, for the flushes can be set to go off as frequently as every five or ten minutes.

The advantages of this apparatus are many.

(1) Accurate estimate of the water supplied to the latrine can be made by timing the flushes, and by simply opening a stopcock, the quantity of water supplied can be increased or decreased readily.

(2) On the whole, the apparatus is cheap; only two per latrine are necessary.

(3) They practically never get out of order, hence obviating the necessity of obtaining special mechanics to repair them.

We consider these advantages place this kind of flush far ahead of any other type at present in use.

From what has gone before it is apparent that the trough closet with syphon flushes is the best design both as regards cheapness and efficiency; we can thoroughly recommend this type, but it must be correctly designed to be satisfactory.

Other minor necessities for a latrine.

In every latrine there must be an adequate supply of water, provided either by taps or in a small tank, from which the coolies can take the water required for

cleansing themselves. An arrangement of a tank placed at the top of the stairs is a very satisfactory plan. Water should also be laid on in pipes in certain places in the latrine to facilitate washing down of the latrine, the floor being sloped towards the drain. The portion of the building under the overhead tanks may be conveniently utilised as urinal as shown in the figs. II (*a*) and (*b*), III (*a*), (*c*), etc.

In a properly designed latrine one or at most two sweepers for every installation are usually sufficient. Of course, if the design of the latrine arrangement is faulty and the fœcal matter does not pass, without some human assistance, into the trough, then more are necessary. The more perfect the design, the less has to be done by the sweeper.

In all septic tank installations it is necessary to keep a rough check on the number of users per diem. In Bengal it is laid down that a self-recording turnstile should be fitted to each latrine. This is very necessary for several reasons. In a mill with a large population, sometimes two or three installations are provided, and if no record is kept as to the number of people going into each, there is a tendency for everyone to use the nearest installation and to neglect the others. Consequently a check has to be kept to apportion the users correctly. Further, in some instances mill-owners have grossly overused their installations; these self-recording turnstiles have been ordered to prevent this. The best form of turnstile is given in fig. II (*l*). It was designed by the Chief Engineer of the Shamnuggur Jute Mill to whom we are indebted for the plan. It is simple, strong and does not get out of order. All flimsy structures are soon demolished by the average mill cooly. The coolies cannot climb over this pattern.

Of course, it is a *sine quâ non* that an ample supply of water should always be available during the 16 working hours. Latrines in arge institutions like workshops and mills are in use more or less at all hours of the day.

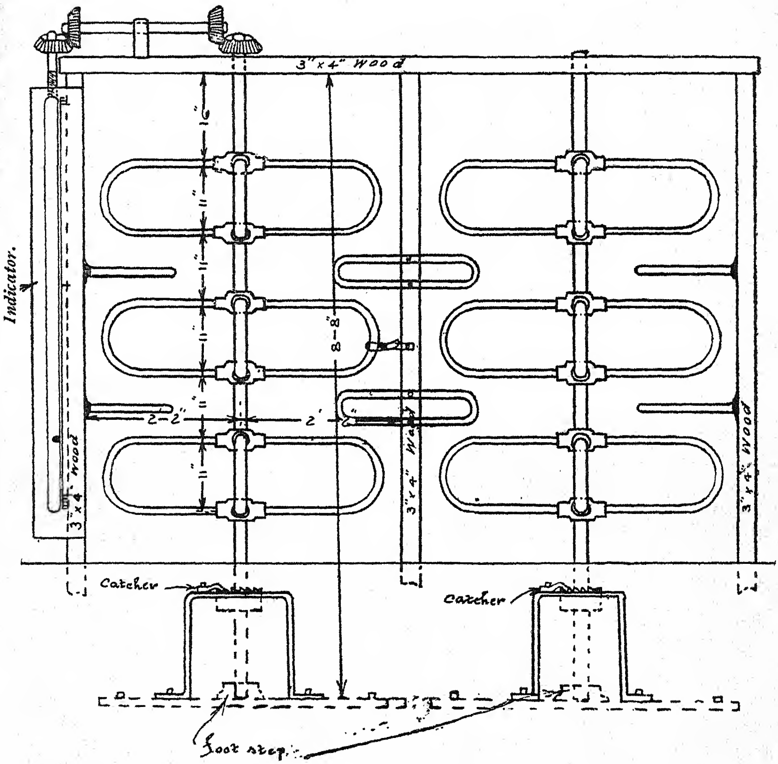


FIG. II (*l*).—Self-recording turnstile.

There is usually a rush between the hours of 6 and 9 in the morning, and 4 to 6 in the afternoon. Consequently, if the flushing arrangements are automatic, it is desirable to quicken up the frequency with which the flushes go off

during these hours. Of course, in the more elaborate arrangement where each user operates his own flush, this is not necessary. There is no necessity to have automatic flushes going off at frequent intervals from 10 P.M. to 6 A.M., the supply of water may be cut off altogether, or so reduced, as to allow only a small quantity to pass into the tank during the night.

The quantity of water for each flush will vary with the design of the latrine, but under ordinary circumstances for a latrine, designed for 2,000 users, nothing under 40 gallons flush is of much use. The slope of the trough should always be sufficient, 1 in 40 being a good working slope. It is astonishing the amount of force that is necessary to thoroughly cleanse these troughs, hence the height between the Syphon tank and the point of discharge into the trough should never be less than 7 ft.; the pipe should never be less than 2 inches in diameter, 3 inches is probably better; the end of the pipe should be flattened out to form a jet to increase the force of the stream. *Vide* fig. III (*a*).

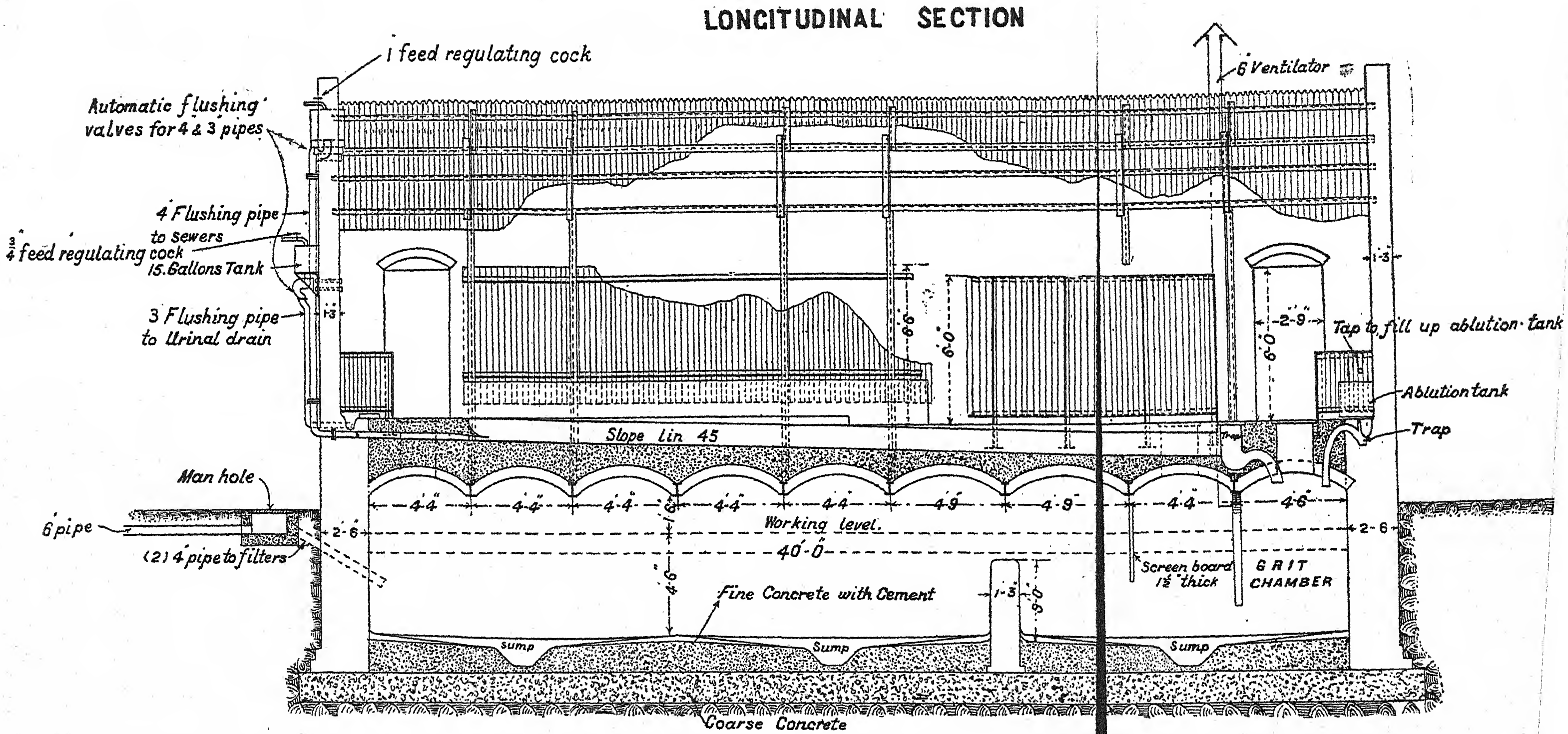
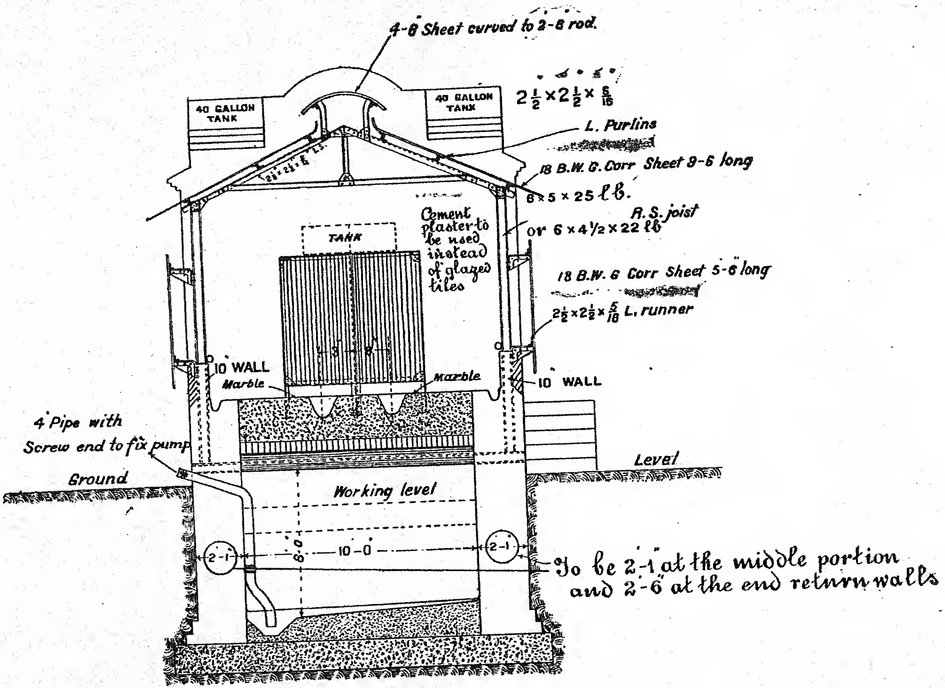


FIG. III (*a*).—Jamalpur Workshop Latrine.



CROSS SECTION

FIG. III (*b*).—Jamalpur Workshop Latrine.

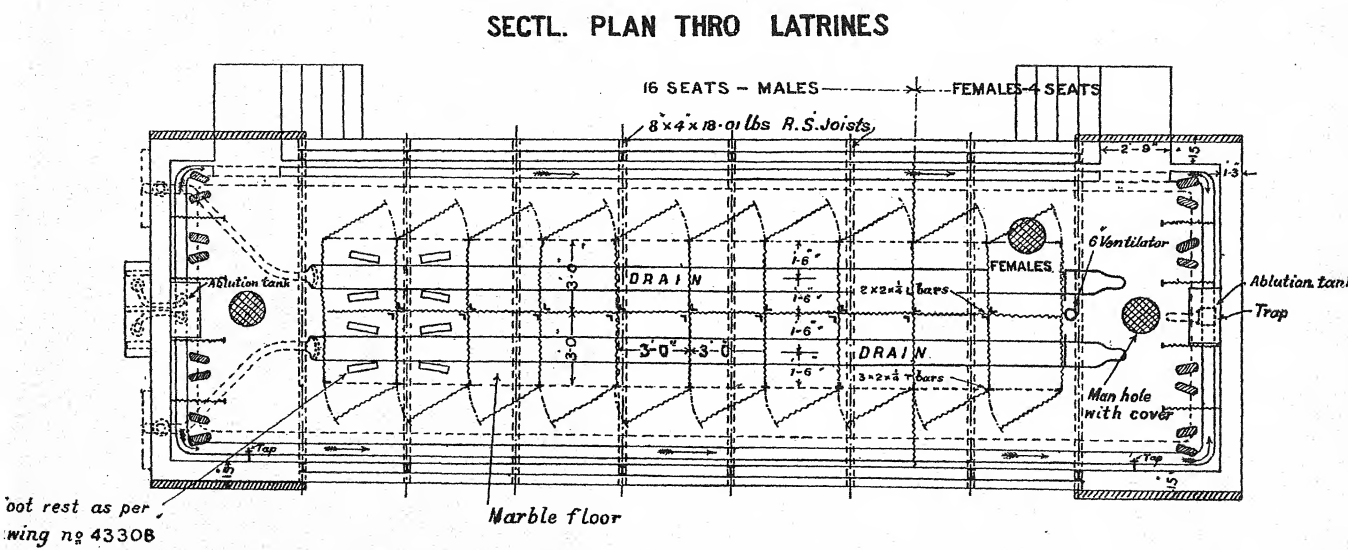


FIG. III (c).—Jamalpur Workshop Latrine.

CHAPTER III.

THE DESIGN OF THE TANK.

IT is not always easy in discussing this subject to avoid introducing purely chemical problems, because there is a scientific reason for most points in the design, but in this chapter an attempt will be made to give a brief description of what we consider to be the best design of the septic tank, without discussing the chemical reasons for adopting any particular idea.

SHAPE OF THE TANK.

The plans give an idea as to what is the best form of design. It is usually admitted that for this work a long and thin tank is the most satisfactory.

As the sewage comes in at one end and flows out at the other, a more equal flow is maintained by adhering to this shape than is the case in a square tank, where stagnation tends to occur at the corners. There is another reason why a tank about five or six times as long as it is broad is desirable, namely, that these dimensions give ample accommodation for a double row of seats in the latrine. In some instances where very large installations are required, to accommodate, say, five or six thousand people, it is usual to place a couple of long

and thin tanks, side by side, so that, although from the outside the tank would appear to be about square, it is in reality two or four long tanks, four or even six rows of seats being constructed in the latrine. A very useful size of tank is (inside tank measurement) $60' \times 12' \times 6' = 4{,}320$ cubic feet $= 27{,}000$ gallons, for about 2,000 users per diem, with 5-gallon flush per user. The breadth of 12 ft. including the thickness of the walls (which adds about 2 ft. on each side, making 16′ in all), gives ample width for two rows of seats, arranged back to back, and for good wide alley ways. It is a comparatively simple matter to design a latrine for a large population, say, 2,000 to 4,000, but it is not easy to get a satisfactory shape of tank, that is both long and thin, and yet sufficiently wide to give ample space for a double row of latrine seats for, say, 400 users. When this difficulty arises, it is recommended that the total width of 10 or 12 ft. be adhered to, but the tank should be divided into two by a longitudinally placed wall. It will be observed that a latrine provided with mechanically-actuated flushes requires a greater width than the trough closet design, because in the former case, an alley must be left between the two rows of pans, in which the flushing gear is located, *vide* fig. II (*c*).

The most economic and satisfactory working depth for a septic tank is 6 feet. Five does fairly well and may be used in places where, on account of the latrine being used in rushes, as at railway stations, very ample seating accommodation is required with a comparatively small tank capacity.

In most active septic tanks there is about 8 to 12 inches of light sludge and the scum is frequently some 6 inches in thickness, so that it is obviously not desirable to decrease the depth below 5 feet.

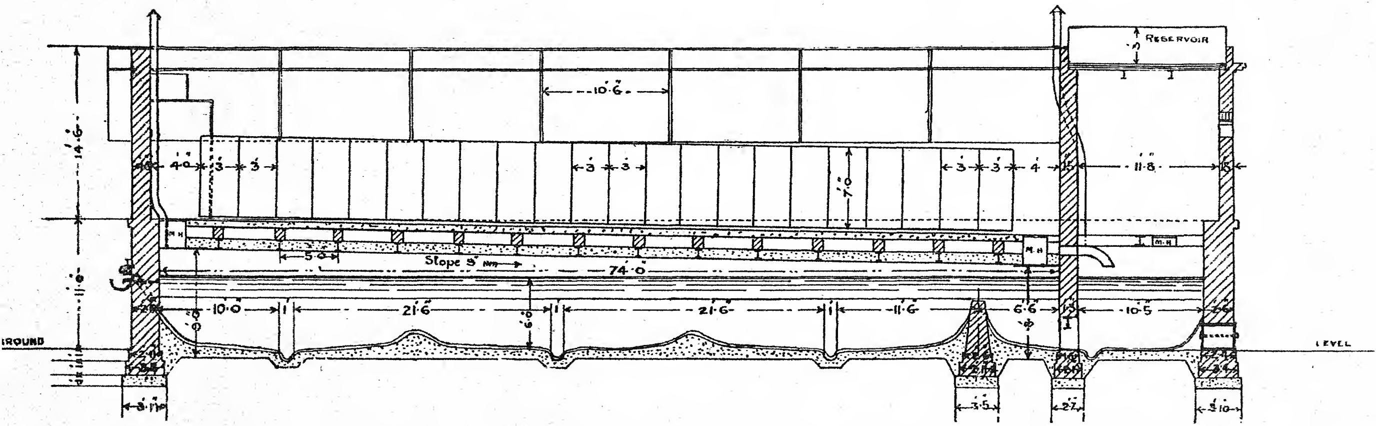


FIG. III (*d*).—Section of Latrine designed for about 2,600 users.

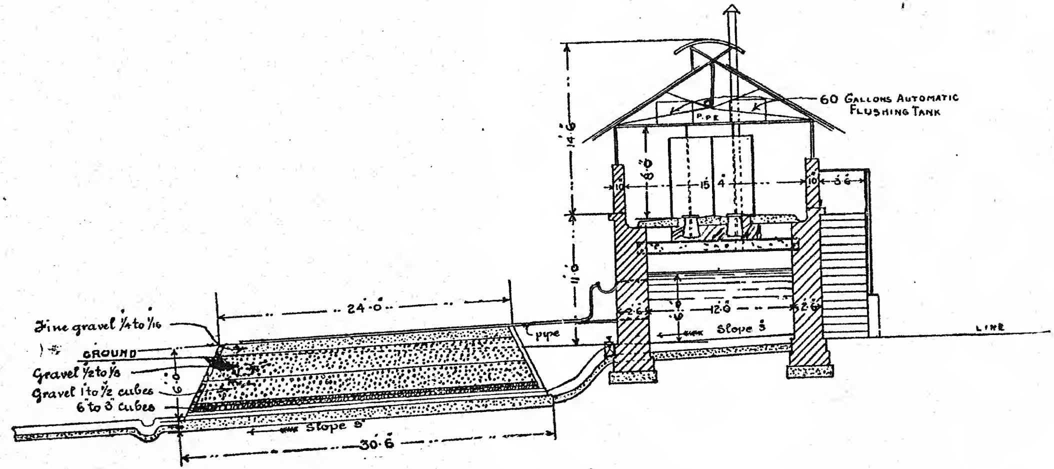


FIG. III (e).—Section.

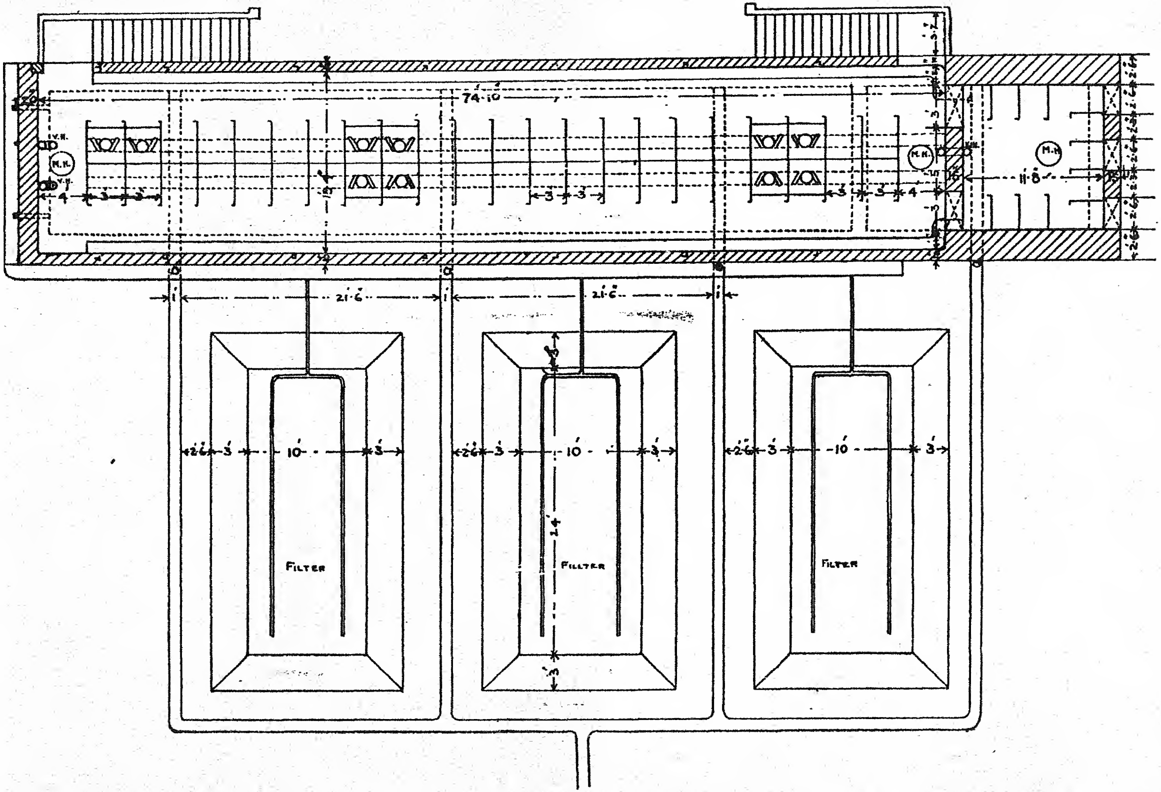


FIG. III (*l*).—Plan showing arrangement of Latrine and heap filters.

Tank capacity necessary.

Without giving any reasons for the statement, tank capacity equal to 12 or 15 gallons per user per diem is found to give the most satisfactory results, and to be the most economical in every way. The discussion as to how these figures have been arrived at may be left for the present. The sewage going into a septic tank of this design is either a 4 or 5 gallons sewage, that is to say, the flushes are usually set to supply about 4 gallons, and one gallon per diem per user is allowed for swilling down the latrine and for the wash water used by the natives of this country instead of paper. Consequently with the sewage of this strength a three days' rest is allowed in the tank. This amount of tank capacity per user may be looked upon as standard for this strength of sewage; from a very large amount of experience it has been proved to give a very satisfactory result.

Grit Chamber.

Very early in our experimental work on septic tanks it was realised, that large and hard masses of fœces would pass unaltered into the tank. It was also reasonable to suppose, that a considerable time must elapse before these masses broke down, or before the material composing them would be sufficiently mixed with water, to allow of the true septic action. Furthermore, it was equally obvious that if these masses passed into the body of the tank, they would eventually accumulate at the outlet end and render the effluent offensive. Consequently in the early designs it was arranged to separate these hard masses. In order to effect this, a division wall was placed in the tank, so as to make a small compartment,

which we now know as the "Grit Chamber." Another reason for designing tanks in this way was, that jute fibre, stones, sacking are not infrequently made use of by the coolies visiting the latrine, and it was necessary to keep these undesirable materials in a separate chamber, from which removal would be easy. It has been subsequently discovered that the secret of success of our tanks, in giving such an extraordinary percentage of purification, is to be ascribed to this arrangement of the grit chamber. The connection between the grit chamber and the tank proper *must always be at the bottom;* the aperture should not be more than a foot, or at the very outside 18 inches, from the base to the edge of the walls. *Vide* fig. III (*a*) and (*d*).

From careful observations we can state that 95% of all masses of fœces float in water, hence as long as the connection between the tank proper and the grit chamber is placed near the floor, there is no likelihood of masses passing into the tank; but it is obvious, that, if apertures are made in the partition wall within a foot of the surface, then more or less broken down masses of fœces would find their way into the body of the tank and would spoil the appearance and purity of the effluent. Practical experience has shown that the capacity of the grit chamber should be one-eighth of the total tank capacity. This point will be further discussed later on. The floor of the grit chamber should always slope sharply in the direction shown in fig. III (*d*), and a large aperture should be arranged at the bottom about 18 inches or 2 feet in diameter to enable bricks and such like materials to be removed easily.

It is not our practice in this country to use scum boards or baffle walls to any extent, because the tanks are shut in, but a simple arrangement is usually put in, so as to allow of running the grit chamber dry, without

emptying the body of the tank. This is done by placing a wall, of sufficient thickness to resist the pressure when the grit chamber is empty, in the position shown in fig. III (*a*) and (*d*). If for any reason it is found advisable to remove the material collected at the bottom of the grit chamber, all that is required is, to open the stopcock and lower the level of the tank as a whole, till it reaches the wall; from this point only the contents of the grit chamber will be drawn off. The large aperture can then be opened and the bricks and stones, etc., removed. By this simple method the activity of the contents of the tank, which usually takes about 12 months to develop to its fullest extent, is not wasted.

Removal of Sludge.

In these days no one believes that 100% of all suspended or solid material will be rendered soluble by the action of the septic tanks. Under the conditions of working in Bengal, where a purely domestic, though a very concentrated, sewage, derived from a population who are al vegetarians, is run into a tank for anaerobic treatment a very considerable amount of suspended matter (possibly as much as 50%) is undoubtedly liquefied; but, of course, some sludge does accumulate, and it is necessary to remove it periodically. Arrangements to carry out this removal must always be made in the design of the tank. Our experience in Bengal is that with a tank working properly, sludge accumulates very slowly. It is always of a light nature, resembling very much the tea leaves that are obtained from soaking tea dust in water. An examination will show that the particles are mostly the husks of rice and dal; this sludge is very easy to remove in a correctly designed tank. The easiest method of getting

rid of the sludge is to provide a fair number of large stopcocks, not less than 6 inches in diameter, situated at suitable intervals down the side of the tank, the bottom of the tank being dished towards these openings. If the tanks are sunk in the ground, it is better to fix a 4-inch iron pipe, leading down into the sump, providing this with a screw coupling at the top end, so that a pump can be easily attached and the sludge removed in this way. Fig. III (*b*) shows a tank designed by myself which has given very satisfactory results. A sludge drain should always be provided outside the latrine to carry away the material when the stopcocks are opened. These drains should not discharge into a river or stream, but should end in a pit filled with gravel or sand. The fluid part of the sludge soaks away into the subsoil; the sludge itself, which is quite odourless, should be removed and trenched.

Discharge Pipes.

The usual way of allowing the effluent to pass out of septic tanks in Europe is by a sil; in this country we find that it is better to take off the effluent at a point half way between the scum and the sludge. By this means it is practically impossible to get large quantities of solid material mixed with the effluent; now and then rushes of black material do occur, due to the fact that a discharge of gas has somewhat disturbed the sludge in the neighbourhood of the discharge pipes. Usually two or three 4-inch pipes of the design given above suffice to carry away the effluent. It is sometimes advisable to put a stopcock at the end of the discharge pipe, so as to try and equalise the flow of effluent. This type of latrine is invariably used irregularly, whether it

be provided for mills, or schools. In jute mills 6 to 9 A.M. and 4 to 6 P.M. are times when there is a considerable increase in the number of users, consequently the rate of discharge of effluent is greater at certain times of the day than at others. This irregularity of flow can be partially remedied by throttling down the discharge with the stopcock, and providing room in the main tank for the sewage to head up. Variations in rate of flow render distribution over the filters more difficult, particularly if only a simple apparatus is made use of. The simple device suggested above assists in equalising matters.

Ventilation Shaft.

One or two 4-inch ventilation shafts should always be fitted to the tank so as to carry away all the gas generated in the tank. These are shown in the plans. As a general rule, it is not worth while going to the trouble of collecting the gas, passing it through lime, etc., in order to utilise it for lighting or power purposes. Large volumes of gas are formed, and mill engineers in charge of installations should be warned not to lower naked lights into tanks, as it is within our experience that small explosions have been caused by this means.

Man-holes.

In the event of any accidental circumstance requiring the tank to be opened up and cleaned out, it is always advisable to have a large number of man-holes. These should be placed, one over the grit chamber, at least two over the tank proper, one at the inlet, and one at the outlet end. These are very necessary for the periodic examination of the quantity of sludge that has accumulated; they are also very useful for taking

samples for research work. It is obvious that if through any unforeseen circumstances the tank requires cleaning out, the more man-holes there are the easier is the work.

WATER-SUPPLY.

The water-supply of the latrine has for the most part been dealt with when speaking of the flushing arrangements. It is usually necessary to store a fairly liberal supply of water in over-head tanks in the latrine itself. Three four-hundred gallon tanks are ample for a latrine designed for 2,000 users, but it is very essential that under no circumstances should there be a scarcity of water; it is easier to imagine than describe the state of a native latrine where the water-supply is deficient. If pumping only goes on for a certain number of hours during the day, the storage capacity must obviously be increased. The space under these tanks can very conveniently be utilised for a urinal. Vide fig. III (*a*) and (*d*).

It may just be mentioned at this point that water supplied to the latrine should be clear and not charged with silt, for it is within our experience that 4 feet of sticky, clayey mud has been found in the septic tank simply due to neglect of this precaution; the silt was only removed with the greatest difficulty.

In a flat country such as Bengal it is usual to build the tanks above the ground; by this means practically no fall is lost, it is desirable to keep the discharge pipes high so that 5 or 6 feet head is available for the filtering process. In undulating localities, where fall is available, tanks may be sunk either entirely or partially in the ground.

It is usual, of course, to provide two staircases to a latrine and to partition off a certain number of seats for the convenience of the women.

CHAPTER IV.

THE STUDY OF THE CHEMICAL ACTION IN THE TANK.

THE study of the chemical action that goes on in the tank as a whole or in the various compartments is a long and somewhat complex subject; it will be necessary to divide it into several separate parts and discuss each separately. The one that we will consider first is the strength of the sewage which is put into the tank.

In the designing of all installations, the first step towards a satisfactory understanding of the problem to be solved, is a complete study of the quality and quantity of the sewage to be treated. In the sewage of large cities, or even in that of smaller institutions, there is considerable variation in the strength at different times of the day. The addition of storm water, trade effluent, etc., which are usually present in the sewage of a large manufacturing town, very materially complicate the question and greatly add to the difficulties of obtaining a satisfactory final result. It will be noted that in the small arrangement, that has already been described in the preceding chapters, none of these difficulties exists. The sewage is, of course, purely domestic, and in a properly designed latrine the variation in the strength is not great, it being composed of the fœcal discharges of one

individual, plus 4 or 5 gallons of water as the case may be; consequently it should not be a difficult matter to obtain thoroughly reliable information as to the chemical composition of such a sewage.

It is obvious that there are many and important differences between a sewage of this strength and character, and the usual material given out by any town in Europe. Firstly, it must be stated that the sewage in our latrines is extremely fresh, that is to say, that it is usually only a matter of minutes from the time that the discharges are voided to the time that they are subjected to the action that is going on in the septic tank. In an ordinary well-looked after latrine there is practically no evidence of the commencement of decomposition in the latrine itself; there can be nothing akin to the action of a chemical nature, which must go on in the sewers, whilst the material is passing down them.

Secondly, another very important practical detail which constitutes a further difference between a European sewage and that obtained in our installations, is, that there is no disintegrating or breaking up action of the masses of fœces in these latrines. Anyone conversant with European sewage knows, that, after the fœcal material and flush water has passed down miles of sewers, a fairly homogeneous emulsion is the result; a certain percentage of hard masses remains it is true, but by far the major portion of the fœcal matter is broken up and mixed intimately with the water. Now, in these latrines this is not so. The maximum distance that the fœcal material has to travel down the soil-pipe or trough is about 40 ft., and much of it does not travel anything like this distance. The consequence is that by far the greater portion of the fœcal discharges are in the form of

hard masses when they enter the tank. It is impossible to over-estimate the practical results of this condition, and we shall endeavour to show that a sewage containing large and hard masses requires entirely different treatment from a well-mixed homogeneous sewage. Of course, all soluble solids, such as are present in the urine, mix intimately with the flush water and pass through the tank at the ordinary speed; but, on account of this peculiar composition of the sewage, the tank must be designed to allow time for the disintegration of these masses.

Thirdly, it should be mentioned, that, unlike a domestic sewage in Europe, there is no paper in a tropical sewage; it has already been explained that practically all natives in this country use water for cleansing purposes. In jute mills, jute fibre and occasionally sacking are made use of, but this is to be regarded rather as an acquired habit, not a usual custom, the women as a rule being the worst offenders in this respect. There is considerable difference between different mills as regards habits of this kind. A certain class of Mahomedans use pieces of brick for the same purpose, and these, though they may give endless trouble in a latrine, cannot, of course, be looked upon as a component part of the sewage.

In order to study the chemistry of this crude sewage, the fœcal discharges from 10 of the coolies employed in the Govt. Vaccination Depôt were collected and mixed with 50 gallons of water; this sewage has been for many years the basis of our experimental work. In this experimental sewage there is only the urine that is passed at the one visit, so that this represents about 20—25% of that passed in 24 hours. From very many hundreds of analyses of the crude sewage, made over a period of

something like four years, the average figures may be given as follows :—

Four hours' oxygen value		26·64	(The water used for making the mixture contains 2·25 pts. of chlorine.)
Chlorine ...	...	6·5	
Nitrogen	Saline ammonia ...	2·64	
	Albumenoid ammonia	5·95	

These results can only be obtained *when the mixture of the fœcal material and water has been extremely thorough*. This, of course, is a very important practical point; for it stands to reason, that if masses remain, it is impossible to get an accurate estimate of the strength of the sewage. In practically all the installations in Bengal, the analysis of the sewage given above may be looked upon as the maximum that would be met with, provided that adequate mixing has been accomplished with 5 gallons of flush water per user. As a matter of fact, it has been amply proved that such a mixture never exists in actual practice. It is only with very great difficulty that we were able to insist on our staff of sweepers making this mixture properly, and in the latrines this would not take place. In order to demonstrate the importance of this point it will be well to allude to an occurrence, which took place in the laboratory, which appeared at the time to be of the nature of an accident. In August 1909, while some work on our model septic tank was in progress, it was discovered, that, comparing the four hours' oxygen and albumenoid ammonia figures in the crude sewage with those obtained in 1906, there was a great reduction, that instead of coming up to the strength given

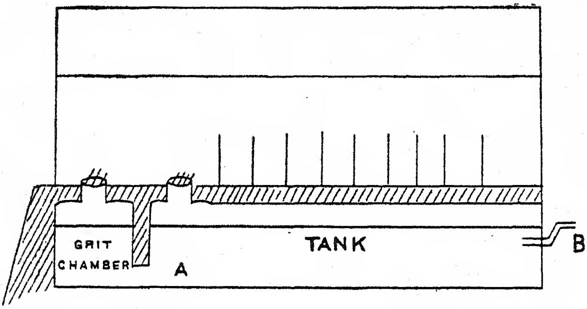
above the following average was obtained from many analyses :—

	Four hours' oxygen value ...	... 10·8
	Chlorine...	... 6·9
Nitrogen ...	Saline ammonia	... 2·3
	Albumenoid ammonia ...	... 2·49

A study of these figures shows that the soluble constituents of the sewage, namely, those that would pass into it in the shape of urine, have not fallen off; in other words, the chlorine and saline ammonia figures are practically the same in both analyses, but the albumenoid ammonia and four hours' oxygen figures are very much reduced. The fact that the soluble products are the same in both goes to show that there has been no error in taking the discharges of 10 individuals, nor could the quantity of water used to dilute the sewage be at fault. It was at once surmised that probably the mixing had not been thoroughly done. An inspection of the work of the staff showed at once that this was the case. At first the accident was looked upon as a deplorable mistake, and one that had occasioned waste of valuable time, but on further consideration, it was remembered that in actual practice, in the public latrines, nothing of the nature of adequate mixing can possibly take place, and that this sewage, on which some valuable work had been carried out, probably very nearly represented the actual strength of the sewage as it enters the tank proper, after removal of the large masses by the grit chamber. Further work on this subject has shown that even these figures are too high in some respects. In an ordinary healthy community, by far the greater part of the fœcal material passed, is of such a consistency that it will not readily mix with water. The following table gives a fairly accurate

estimate of the strength, according to the amount of mixing employed:—

	Chlorine.	4 Hrs.' Oxygen.	Saline Ammonia.	Albumen. Ammonia.
Thoroughly mixed sewage	6·4	26	2·46	5·95
Partially ,, ,,	6·4	10 8	2·30	2·45
Unmixed sewage	6·4	7	2·30	1·2



It is easily demonstrated that the sewage as it leaves the grit chamber and enters the tank proper, is practically the same strength as the unmixed sewage in the table above, for by taking samples at A in the plan, we obtain a similar mixture, *viz.*, the crude sewage with all the masses retained in the grit chamber. The results of some analyses are as follows:—

	Chlorine.	4 Hrs'. Oxy.	Saline Ammonia.	Albumenoid Ammon.
Average of eight samples from one latrine (7-gallon dilution) ...	3·42	4·12	2·77	·76
Average from six samples from various latrines (5-gallon dilution) ...	6·0	9·23	7·01	1·06

It will be seen that the first of these very closely resembles the unmixed sewage, whilst the second that of the partially mixed, the high free ammonia figure being due to the septic action in the grit chamber.

Now, the important points to remember in connection with the working of these septic tank latrines are: (1) that when these masses are separated out, they represent a very large proportion (from 60—80%) of the solid organic matter in the sewage which has to be acted upon; (2) that due to the design of the grit chamber, these masses *are actually* separated out from the sewage and remain behind in this chamber. Consequently, in the tanks as we design them, we have at least two different actions:—

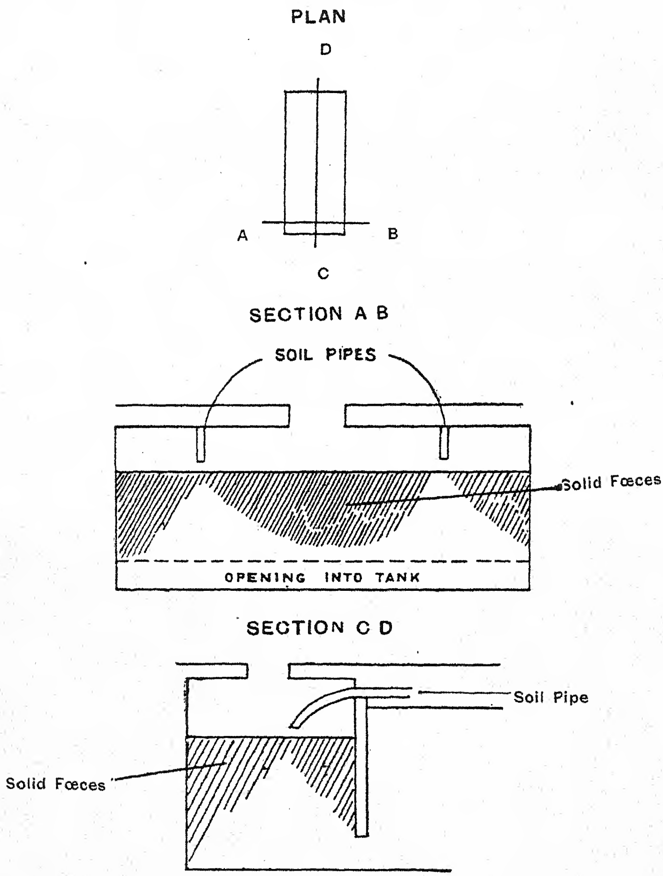
(1) an action which is going on in the grit chamber in the masses of fœces that are retained in this compartment;

(2) an action which is going on in the tank proper.

Before going into a long discussion of the action which takes place on the fœces in the grit chamber, it may be stated, that an inspection of one of these tanks gives us very valuable information. On removing the man-hole cover, it is observed that apparently the whole of the grit chamber contains a solid mass of fœces. If sections are made in various parts of this chamber, it is found that the mass may be 2 or even 3 feet thick in certain places, particularly in the corners. Under each soil-pipe there is a free channel, through which the fluid part of the sewage passes into the latrine. The rough diagram given below explains the situation better than anything else.

Now, it may be supposed that if the major portion of the solid discharges of some 2,000 users per diem, are retained in this comparatively small chamber, that, it is only a case of time, when the whole latrine will be

sludged up solid; the general appearances of a grit chamber seem to confirm this very natural surmise. That this accident does not take place, is proved by



the fact, that we have in the neighbourhood of Calcutta no less than eight latrines, that were erected in 1902; these have never given a day's trouble; the grit cham-

bers have never been cleaned out or in any way touched. Consequently it is perfectly obvious, that if a large amount of solid fœces is daily added to the mass in the grit chamber, a corresponding amount of breaking up must also be taking place, and the disintegrated masses must be passing with the flush water into the tank proper; were this not so, the accumulation of fœces would soon render the latrine useless. There appears to be very little doubt, that many of the harder masses of fœcal material must remain in this chamber for weeks or possibly months before they disintegrate.

In one particular latrine, namely, Shamnagar Jute Mill, the labourers have contracted the very bad habit of using jute fibre for cleansing purpose instead of water. The consequence is, that not only is the grit chamber filled up with a mass of what is practically solid fœcal material, but this is held together by a strong network of jute fibre. Although the latrine has been in operation for seven years, the grit chamber is working admirably and shows no signs of being blocked. Of course, this great mass of jute must eventually upset the working of the latrine unless it is removed, but there can be no doubt as to the main contention, namely, that with a properly designed grit chamber the rate of collection of fœcal material is not greater than the rate at which the mass breaks down.

Now, if it is granted that the average stay of the solid fœces in the grit chamber is anything between three days and three months, during this lengthy period a very large amount of chemical action must go on. We are aware that the substance, which we call fœces, is a very highly complex mass, made up of millions of organisms, the remnants of enzymes secreted by the intestinal mucous membranes, and the particles of matter

derived from the food. It is therefore to be expected that actions of many kinds will be taking place in the fœces during the period of rest in the grit chamber.

In order to definitely prove this point samples of this mass were collected and examined. In most cases the portions were obtained from a part of the grit chamber at a considerable distance from the inlet pipes, so as to ensure getting specimens that had been some time in the chamber. The results of these analyses are given in Table No. IV*a*, and they are extremely interesting and striking.

Each sample was analysed in exactly the same way, the method being as follows :—

Every bottle of material was carefully mixed and any large particles such as sticks, jute fibres, etc., separated out. 10 grammes of this cleansed material were weighed out and put in 1 litre of water ; the mixture was then analysed very fully.

To form a basis of comparison, three precisely similar mixtures were made *from the fresh fœces* of 10 coolies in the depôt. The percentage of water present in each sample prior to making the mixture was carefully estimated; it will be observed that the variation is not great, so that, broadly speaking, the results obtained from the various samples are fairly comparable.

The samples Nos. I and II taken from Shamnagar are very remarkable. As already stated, the grit chamber is full of jute fibre, and this binds the mass together and prevents the flowing away of the fœcal material, even when it has become fluid. The probabilities are, that these samples are actually the oldest of the whole series. The results of the analyses should be carefully compared with those of the fresh mixture. It will be observed that the four hours' oxygen figure of the Shamnagar

TABLE IV(*a*).

ANALYSIS OF FŒCES FROM GRIT CHAMBERS.

Date.	Origin.	1. Percentage of water in the samples.	2. Chlorine.	3. 4 Hrs.' Oxygen-value.	4. 4 Hrs.' Oxy.-value after clarification.	5. Colloid Organic.	6. 3 Minutes' Oxygen-value. Before incubation. A	6. After incubation. B	6. Difference between A & B.	7. Nitrogen. Saline and free.	7. Albumenoid Ammonia.	7. Nitric and Nitrous.	8. Amount of Dissolved Oxy. left dilution 1 in 10. After 24 hours.	8. After 48 hours.	9. Period required to Nitrify.	10. Total Nitrogen by Kjeldal (per cent. of dried residue).	Remarks.
31-1-10	Shamnagar I	86·52	1·2	6·97	·84	6·13	2·79	3·20	·41	·59	2·15	*Nil*	·40	·32	20 days	2·48	Very old samples grit chamber containing jute fibre.
31-1-10	„ II	85·96	1·2	6·41	·91	5 5	2·23	3·00	·77	·54	1·79	„	·46	·38	19 „	2·69	
17-2-10	Hastings I	84·17	1·4	16 79	4·75	12 04	6·31	6·71	·40	1·60	3 10	„	·01	*Nil*	14 „	5 20	Taken near discharge pipe.
17-2-10	„ II	82·30	1·8	15·87	3·76	12·11	6·07	6·50	·43	2·77	2·40	„	·02	„	14 „	4·1	Taken further away.
17-2-10	„ III	83·78	1·2	13·21	2·47	10 74	5·02	6·25	1·23	3·20	1·89	„	·42	·29	12 „	3 84	Taken in corner old sample.
25-2-10	Tittagarh I	85·41	·8	13·78	1·58	12·2	3·37	4·00	·63	1·23	1·03	„	·04	*Nil*	11 „	3 37	Latrine working for 6 years.
25-2-10	„ II	86·13	1·0	11·72	1·71	10·01	3·58	4·20	·62	1·35	1·09	„	·05	„	8 „	3·0	
28-2-10	Standard I	79·37	1·2	17·52	1·33	16·19	7·15	7·92	·77	1·89	1·80	„	·41	„	11 „	2 3	
28-2-10	„ II	82·55	1·2	17·71	1·24	16·47	6·35	7·10	·75	2·31	1 62	„	·54	·21	13 „	3·3	
28-2-10	Tittagarh III	82·30	1·0	18·28	1·52	16 76	6·35	7·18	·83	2·46	1·84	„	·34	*Nil*	14 „	3·18	
3-3-10	Bengal Cotton Mill	83·21	1·2	9·89	1·56	8·33	4·42	4 66	·24	·80	1·67	„	·14	„	17 „	3 87	
3-3-10	Desi Cotton Mill	84·96	1·0	10·37	1·29	9·08	2·77	4·01	1·24	·80	1·88	„	·22	„	19 „	3·66	
3-3-10	Clive Jute Mill	81 48	1·2	17·69	1·22	16·47	11·41	12·87	1·46	2·71	2·15	„	·04	„	19 „	3·92	
5-3-10	Victoria Jute Mill I	81·43	1·0	18·14	2·00	16·14	9·22	10 30	1·08	1 04	1·61	„	·22	„	16 „	3·03	
5-3-10	„ II	85·33	·8	16·81	1·74	15·07	7·10	8·10	1·00	1·89	1·65	„	·46	„	17 „	4·31	
5-3-10	„ III	86·44	1·0	16·03	1·91	14·12	7 34	8·70	1·36	1·60	2·32	„	·46	„	17 „	3·96	
Mixture of fresh fœces from 10 individuals.		80 21	1·4	12·05	1·89	10·16	5·39	6·92	1·53	·76	3·47	„	1 in 20 ·27 1 in 10 *Nil*	„	32 „	5·55	
„	„	81·9	1·8	10 68	1·64	9·04	4·24	6·54	2·30	·44	2·40	„	1 in 20 ·09 1 in 10 *Nil*	„	29 „	5·64	
„	„	80·1	2·0	11·28	2·20	9·08	...	...	...	·86	3·32	„	1 in 50 ·23 1 in 10 *Nil*	„	30 „	5·58	

sample is only about half that of the fresh mixture, and the three minutes' oxygen value is extremely low. There is a very small quantity of saline ammonia; the albumenoid ammonia is also very low; the sample contains very little easily oxidisable matter, for the amount of dissolved oxygen taken from water in the solution of 1 in 10 in 48 hours is very small. The Kjeldal or total nitrogen figure is under half of what it is in the fresh fœces.

The next series of samples taken from Hastings Mills are also very important. These 3 samples were all taken from the same grit chamber on the same day. No. 1 was taken close up to the soil-pipe where practically nothing but fresh fœces would be caught. No. 2 was taken further away from the soil-pipe, and No. 3 right in one corner of the grit chamber. A comparison of the figures is extremely interesting. Four hours' oxygen, 3 minutes' oxygen, albumenoid ammonia and the total nitrogen figures show a progressive falling-off between the samples 1, 2 and 3; on the other hand, the saline ammonia is increased in inverse order. The difference between the absorptive power of dissolved oxygen is marked between the samples 1, 2 and 3, demonstrating the fact that rapidly oxidisable matter, in the third sample, is not large in amount and not in such a condition as to readily take up oxygen from water.

Of the remaining samples nothing special need be said as they are more or less alike. They all demonstrate the difference between the fresh mixture and that made with fœces from the grit chambers.

It may, however, be well to say something on the various columns in this table. The percentage of water in these various samples varies so little that the actual results may be compared; therefore it has not been thought

desirable to reduce them to a common denominator. It should, however, be stated that the total nitrogen figures are obtained from the dried residue and are strictly comparable in all samples.

The chlorine figure calls for no particular remark; diffusible salts like chlorides would not be retained in the mass very long.

The 4 hours' oxygen figures are very extraordinary. Considering that we have absolutely no means of estimating how long these various samples have remained in the grit chamber, it is to be expected that considerable variations would occur in this column. The two most important points are: (1) the very low figure obtained from Shamnagar, (2) the fact that in nearly every other case the 4 hours' oxygen value is higher in the grit chamber fœces than it is in the fresh mixture. The reason for this variation has been demonstrated by a second series of experiments, which will be referred to later on, but it may be briefly stated, that if a mixture of fœces is allowed to stand in a bottle, at first the 4 hours' oxygen value steadily increases, due undoubtedly to the putrefactive changes that go on, but finally there is a decrease. Hence, taking the average of these 12 samples, 10 of these represent the stage when decomposition has gone on to a considerable extent, the 4 hours' oxygen figure being increased. The 2 Shamnagar samples show that they are probably in a later stage than this, due to the prolonged stay in the tank on account of the presence of jute fibres in the mass. This explanation is borne out by the results in column 8; in many instances where the 4 hours' oxygen figure is extremely high (particularly in the Standard and Victoria Jute Mills, Nos. 1, 2 and 3) the amount of oxygen left after 24 hours is very considerable, but

it is practically *nil* after 48 hours; in the Shamnagar samples the amount remaining after 48 hours is still great.

The researches of Drs. Fowler, Evans and Oddie have provided a very simple and ready method of estimating the amount of colloids, that are present in a given effluent. The method is as follows:—Colloid material is readily precipitated from the fluid, in which it is held in suspension, by either basic ferric acetate, or ferric aluminum alum; a four-hours' oxygen absorption from potassium permanganate, before and after clarification with these salts, has been shown by the originators of the test to give a satisfactory estimate of the amount of colloid organic matter precipitated by the salts.

A glance at the colloid organic column (No. 5) shows some very remarkable results. The figures should be carefully scrutinised, for, there seem to be two separate sets of results obtained in the samples; one, those in which the colloid figure is practically the same as in the fresh mixtures (*vide* the Hastings Mill, the Bengal Cotton Mill, the Desi Cotton Mill and the Tittagarh Mill samples); and another series, where there is a great increase, *vide* Standard, Clive and Victoria Mill results. Considering there is every reason to believe that all the samples of fœces have remained for a long time in the grit chamber, the lack of uniformity in amount of colloid organic matter is distinctly odd, particularly when it is noticed that the amount of crystalloid organic is very much the same in all samples. One is forced to the conclusion that the colloid material has actually increased in the latter group of samples side by side with the four hours' oxygen figure. On the other hand, the three samples from Hastings Mill (all of which, it should be remembered,

came from the same grit chamber) should be noted. In these, although the four hours' oxygen figures shows a falling-off in the three samples, the variation is due largely to the disappearance of crystalloid organic matter. The only explanation that one can give of these very discordant results is, that, apparently in some samples, there exists a material of a colloid nature, which before putrefaction does not take up oxygen from potassium permanganate in 4 hours, but that after putrefaction, the products, though still remaining colloid, do seize oxygen from this salt. In the original paper by Dr. Fowler it is distinctly laid down that the method does not pretend to give the absolute total amount of colloid present, but only those which are readily oxidised by potassium permanganate. These figures, therefore, tend to show that there may be other colloids occasionally present in fœces, which, prior to putrefactive action, are not easily oxidisable. It is probable that this particular kind of colloid does not exist in all samples of fœces.

The incubator test figures are somewhat erratic. It is fairly certain that the Shamnagar samples represent the oldest fœces in the series, and yet the difference between the putrescibility of this sample and others is not very great. There is, for instance, no parallelism between the putrescibility test and the amount of dissolved oxygen remaining. In the three Hastings samples, the oldest of the lot, and the one that takes up least dissolved oxygen, is infinitely the most putrescible according to the results. We have always maintained that without the presence of hydrogen sulphide the putrescibility test is of no value whatever to the sewage analyst in the East, and the extremely discordant results given in these figures confirm this opinion.

Concerning the saline ammonia figures, it is not advisable to make any very strong statement as considerable variation occurs. Free ammonia is very diffusible in water, and even if large quantities of complex bodies were reduced to simple ammonia, the salt would rapidly diffuse away in the stream of water passing to the tank. It should, however, be noticed that in the grit chamber fœces, there is a very material increase over the figures obtained from fresh fœces. It should be stated that the mixture of fresh fœces was made without a drop of urine being added.

The albumenoid ammonia figures show much greater evenness. They are all lower than the average figures of the three fresh mixtures. Speaking broadly, the albumenoid ammonia figures in the grit chamber fœces samples show a distinct falling-off from those of the fresh.

By far the most important column of figures in this table is the result of the total nitrogen as obtained by Kjeldal's process. The figures are extremely striking. In fact, it may reasonably be maintained that taking the total nitrogen of the dried residue of fresh fœces, as being 5·5% by weight, the amount of destructive action that has gone on in the grit chamber may be represented by the difference between the total nitrogen figure of each sample and 5·5%. It will be observed that the lowest total nitrogen of the whole lot are the Shamnagar samples. The difference between the total nitrogen figures of Hastings samples has already been alluded to ; figures of the remaining samples bear out this contention to an extraordinary degree. The loss of nitrogen is probably accounted for by the fact that complex bodies have been broken down into ammonia, and the ammonia has diffused away in the current of water, that is always passing

through the grit chamber. Some of the loss may be accounted for by free nitrogen being discharged as a gas, but there is no evidence that this is the case.

The figures giving the amount of dissolved oxygen taken up from tap water are extremely important. The 24 hours' figures are interesting when compared with those of the analysis of fresh mixture. It will be observed that fresh fœces contains certain material, which will seize dissolved oxygen in water with extraordinary rapidity. The mixtures of the grit chamber fœces, all of them, without exception, show that they have lost this great avidity for oxygen to a considerable extent, and that, although the four hours' oxygen absorption figure from potassium permanganate is in some cases considerably increased, the amount of dissolved oxygen taken from water is considerably less than the mixtures made with fresh fœces. The 24 and 48 hours' oxygen figures give a very ready method of showing the various degrees of avidity for oxygen. The very old samples take up very much less, even in 48 hours, than do the newer ones.

The period required to nitrify a mixture of the samples and equal quantities of tap water, shows a considerable difference between the grit chamber samples and the fresh fœces. Apparently the reason why the Shamnagar sample takes so long a time to nitrify is that nearly all the ammonia has diffused away. We do not propose to lay any very great stress on this test, because it is admittedly of a rough-and-ready character, but there is no getting away from the fact, that, these mixtures of grit chamber fœces in water take about fifty per cent. less time to nitrify than a precisely similar mixture of fresh fœces.

Therefore, in conclusion, we consider that it is proved beyond any shadow of doubt, that during the stay in the

grit chamber, the mass of fœces is broken down, it loses a large proportion of its nitrogen in the shape of ammonia, that it loses the power of absorbing dissolved oxygen from water to a marked degree, and finally that it is in a fairly suitable condition for nitrification.

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CHAPTER V.

THE STUDY OF THE CHEMICAL ACTION IN THE TANK.—(*Contd.*)

BEFORE leaving the subject of the chemical changes which go on in the mass of fœces in the grit chamber, it is necessary to refer to another series of experiments, that were started with the intention of further increasing our knowledge on the subject of the putrefaction of fresh fœces.

A description has already been given of an ordinary grit chamber, and it has been pointed out that to the naked eye it appears to be full of solid fœces. It was decided that it was desirable to study what changes took place in any mass of fresh fœces when kept for a considerable length of time, whether in a grit chamber or bottle. Consequently a mixture of the fœcal discharges of 10 men (without urine) were stirred into a homogeneous mass; this thick mixture was placed in a bottle and allowed to remain at the ordinary room temperature; analyses were made weekly.

In the first series A1, A2, etc., care was not taken to exclude flies from access to this mass; the consequence was that in a very few days the material became full of maggots derived from flies' eggs. We have never seen this condition in a grit chamber, for speaking broadly, it is impossible for flies to enter a tank, the man-hole covers fitting tight.

TABLE V (*a*).

WEEKLY ANALYSIS OF FŒCES KEPT IN A BOTTLE.

Date.	Origin.	Percentage of water in the original.	Chlorine.	4 Hours' Oxy.-value.	4 Hours' Oxygen-value after clarification.	3 MINS.' OXY.-VALUE.		NITROGEN.			AMOUNT OF DISSOLVED OXY. LEFT.		Period required to Nitrify.	REMARKS.
						Before incubation.	After incubation	Saline and free.	Albumenoid Ammonia.	Nitric and Nitrous.	After 24 hours.	After 48 hours.		
17-1-10	A I	80·21	1·4	12·05	1·89	5·39	6·92	·76	3·47	*Nil*	In dilu. 1 in 10 *Nil* 1 in 20 ·27	1 in 20 *Nil*	32 days	
24-1-10	A II	"	1·4	12·00	1·88	5·00	6·47	5·77	3·16	*Nil*	1 in 10 *Nil* 1 in 20 ·44	1 in 20 *Nil*	29 "	
9-2-10	A III	"	1·6	14·15	*Nil*	*Nil*	*Nil*	6·50	3·34	*Nil*				

The method of a nalysis is the same as in Table IV (*a*), *viz.*, 10 grams of emulsion were added to 1 litre of water.

Analyses were, however, made on the three consecutive weeks; the results are given in Table V (*a*). After this time it became impossible to take samples for analysis, on account of the number of maggots, and as this condition of affairs was different from normal, there did not appear to be any object in continuing the work on this mixture. A second series B1, B2, etc., were made on exactly the same lines, this time care being taken to exclude flies from the vessel. The figures obtained from weekly analyses are given in Table V (*b*), and they give much valuable information. In the figures given opposite, the following points should be observed:—

(*a*) The steady rise from week to week in the amount of oxygen absorbed in 4 hours from potassium permanganate. Apparently the increase in these figures takes place during the first 3 or 4 weeks; after that they appear to be stationary. The probable explanation of this fact is, that, certain bodies in a fresh state do not take up oxygen from potassium permanganate, but the products of the putrefaction of these bodies do.

(*b*) A reference to the colloid organic column shows that the colloid material in this mixture remains practically stationary, and that the increase in the 4 hours' oxygen figures is due to crystalloid oxidisable material and not to colloids. This is not always the case; some other results show an increase in the colloids. (*Vide* Table IV (*a*)).

(*c*) The ordinary incubator test figures seem to be somewhat erratic, but, on the whole, it would appear that there is a distinct

falling-off in putrescible matter. We, however, make this statement with very great reserve because the results obtained with this test are always very variable.

(*d*) Coming to the nitrogen figures, we find, as one would expect, a steady, but somewhat slow, increase in the saline ammonia; but it is extraordinary that a similar increase in the amount of albumenoid ammonia is also observed. The increase in the saline ammonia must be at the expense of albumenoid ammonia, and yet, even making allowances for this, the albumenoid figure is higher at the end of 10 weeks than it was at the commencement. The explanation of this fact is not by any means apparent, but it would appear, that, owing to putrefactive changes, some of the nitrogen that would in the fresh state be classed as "residual nitrogen," now comes over in the distillation with alkaline potassium permanganate.

(*e*) The amount of oxygen absorbed from tap water in 24 to 48 hours is given, and it will be observed that the amount remaining steadily decreases; that is to say, as putrefaction goes on, the avidity for oxygen is also increased.

Further work on this subject is in hand.

Hence, from the above analysis it is distinctly shown that, during the first 10 weeks in the process of putrefaction, the 4 hours' oxygen figure, saline ammonia figure, and the power of absorbing oxygen dissolved in

water steadily increases due to the breaking down of the various constituents of the fœces.

Unfortunately it cannot reasonably be claimed, that fœces stoppered up in a Winchester quart bottle, are under precisely similar conditions to those in the grit chamber, for, in the latter case, a constant stream of water is passing through and around the mass. This is fairly certain to modify the results of analysis even if it does not alter the process of putrefaction, for diffusible salts, such as free ammonia, will probably be slowly removed. But a glance at Table IV (*a*) shows that the putrefactive changes that go on, both in the bottles and the grit chambers, are not essentially different. Thus, in both series the 4 hours' oxygen figure is usually higher in old samples than in the fresh mixture. The saline ammonia figure also shows a very considerable increase, but it cannot be said that the albumenoid ammonia figures show a similar increase in the grit chamber samples; on the whole, a reduction is noticed.

Another instance of apparently contradictory results is seen in the amount of colloid material in the grit chamber fœces as compared with the samples of the emulsions in the bottles. From the figures given in Table IV (*a*) it appears that there is a distinct indication that the actual amount of colloid material in the grit chamber fœces is sometimes increased, whereas results obtained from the emulsion in the bottles show that there is little or no increase. The explanation of this fact has already been suggested, but much more work is required before it can be considered proved.

The more of these discrepant results we obtain, the more one feels justified in stating that the action known as putrefaction is very complex and varied; in some

samples one action preponderates and in others something entirely different is observed. It has been proved (*vide* Appendix to the Madras King Institute's Report for 1909), that extraordinary variation in the bacteriological flora of fœces exists at different times of the year. Therefore it is not to be wondered at that apparently contradictory results are met with, in such a large subject as the putrefactive changes which go on in fœces. Although these figures open up a very wide field of speculation, they do not in any way alter our original conclusion; indeed, they tend to confirm it, *viz.*, that while the fœces remain in the grit chamber, a very large amount of breaking down action is taking place, all of which is in the direction we desire.

Before finally closing this subject, the figures obtained in emulsion A1, A2, etc., Table V (*a*), should be compared with those of B1, B2, etc., Table V (*b*). It will be remembered that A1 contained thousands of maggots, and, as a result, the process of breaking down seems to be extraordinarily rapid, *vide* the saline ammonia figures; after only one week there is a rise from ·76 to 5·77; presumably the maggots fed on some substance in the fœces and excreted a solid more or less allied to urea. This affords chemical proof that animal life, much higher in the scale than bacteria, can, under certain conditions, assist in the action that we are endeavouring to bring about.

In the preceding chapter we have proved that a considerable proportion of the total breaking down action goes on in the grit chamber. We will now discuss the amount and the kind of action which takes place in the tank proper. In order to study this point, samples were collected from the sewage as it entered the tank proper, that is, at the point A in the diagram, and compared

TABLE V (b).

WEEKLY ANALYSIS OF FŒCES KEPT IN A BOTTLE.

Date.	Origin.	Percentage of water in the original.	Chlorine.	4 Hours' Oxygen-value.	4 Hours' Oxygen-value after clarification.	Colloid Organic.	3 Minutes' Oxy.-value. Before incubation.	3 Minutes' Oxy.-value. After incubation.	Nitrogen. Saline and free.	Nitrogen. Albumenoid Ammonia.	Nitrogen. Nitric and Nitrous.	Amount of dissolved Oxygen left. After 24 hours.	Amount of dissolved Oxygen left. After 48 hours.	Period required to Nitrify.	Remarks.
28-11-10	B 1	80·21	1·8	10·68	1·64	9·04	4·24	6·54	·44	2·40	*Nil*	1 in 10 ·02 1 in 20 09	1 in 20 *Nil*	29 days	
3-2-10	B 2	,,	1·8	12·81	1·69	11·12	6·41	6·30	·87	2·47	,,	1 in 10 *Nil*	1 in 10 *Nil*	24 ,,	
10-2-10	B 3	,,	1·6	13·26	2·74	10·52	4·44	5·71	1·23	2·74	,,	1 in 10 *Nil* 1 in 50 ·36	1 in 50 ·29	26 ,,	
16-2-10	B 4	,,	1·6	15·24	3·20	12·04	6·04	6·25	1 23	2·96	,,	1 in 50 ·32	1 in 50 ·01	27 ,,	
23-2-10	B 5	,,	1 4	15·70	3·40	12·3	6.50	6·70	1 60	3·07	,,	1 in 50 ·31	1 in 50 *Nil*	24 ,,	
2-3-10	B 6	,,	1·2	15·75	4·10	11·65	6·50	7·30	1 60	3·10	,,	1 in 50 ·29	,,	22 ,,	
10-3-10	B 7	,,	1·2	15·11	3·43	11·68	6·50	6·60	2·31	2·85	,,	1 in 50 ·21	,,	21 ,,	
17-3-10	B 8	,,	1·2	15·17	3·11	12·06	6 54	6 84	2·71	3·14	,,	1 in 50 ·21	,,	21 ,,	
24-3-10	B 9	,,	1·4	15·49	3·22	12·27	6·32	*Nil*	2·83	3 13	,,	1 in 50 ·22	,,	20 ,,	
31-3-10	B 10	,,	1·4	15·94	3 58	12·36	*Nil*	,,	2·95	3.01	,,	1 in 50 ·15	,,	21 ,,	
6-4-10	B 11	,,	1·4	15 13	3·83	11·30	6·54	7·00	2·95	3·09	,,	1 in 50 ·09	,,	21 ,,	
14-4-10	B 12	,,	1·4	15·18	3·99	11·19	6·33	6 86	2·95	3·13	,,	1 in 50 *Nil*	,,	19 ,,	
20-4-10	B 13	,,	1·4	15·30	3·90	11·40	6·66	7·00	3·08	3·23	,,	1 in 50 *Nil*	,,	19 ,,	
28-4-10	B 14	,,	1·4	15 93	4 06	11·87	7·6	7·10	3·20	2·92	,,	,,	,,	20 ,,	
5-5-10	B 15	,,	1·4	15·80	3·93	11·87	7·10	7·20	3·46	2·91	,,	,,	,,	20 ,,	

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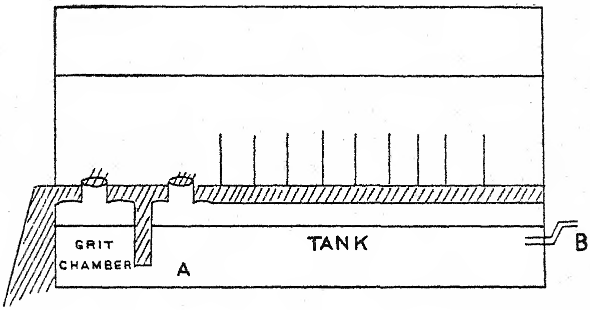
with samples taken from the discharge pipe, at the point B.



The tank at Shamnagar was selected for the study of this point; it is at least 8 years old, it is worked with very great regularity, the flushes are kept in good order, and a careful record of the number of users per diem is also maintained. Table V (*c*) gives the result of these analyses in pairs; what are here described as "grit chamber" and "discharge pipe samples" were taken at the same time on all occasions.

It will be observed that the results are wonderfully even, so that it will not be necessary to comment on any particular pair; our remark can be confined to the averages given at the bottom of the table. By far the most striking point, which is to be noticed in these figures, is the extraordinary small difference between the inlet and the outlet samples; that is to say, that the amount of action which has gone on in the tank is apparently very small. The percentage of purification between samples taken at A and B is, on the 4 hours' oxygen figure, only 18·5%, and that calculated on the albumenoid ammonia figure is 19·2%. But if we

estimate the total purification of the whole installation, we find, that, in this particular latrine, the proportion carried out in the tank itself is almost negligible. It is possible to calculate the percentage of purifying action carried out in each compartment (grit chamber and tank proper) in the following way.

In order to estimate the original strength of the sewage as it entered the grit chamber, the number of users per diem was carefully counted by a self-recording turnstile, and the quantity of effluent was also gauged during 24 hours. By dividing the former into the latter, it was shown that the actual dilution was one user to about 7 gallons of water. (The tank was designed to give a 5-gallon sewage, but it is provided with mechanical flushes; these introduce an element of uncertainty, such factors as the children in the mill playing with the mechanism have to be reckoned with, so that in this instance, several gaugings showed the actual strength of the sewage to be approximately 7 gallons per user.) The analysis of 7-gallon sewage *thoroughly well mixed* would be—

Crude Sewage.		Sewage at A.	Final Effluent at B.
Chlorine ...	4	3·8	3·8
4 Hrs.' Oxygen ...	16	4·12	3·36
Albumenoid ammonia...	4·5	·78	·63

Consequently the total purification from the inlet to outlet is 79% on the 4 hours' oxygen and 86% on the albumenoid ammonia figures. This is a distinctly satisfactory result. But as we are in possession of the average analysis of the mixture as it enters the tank proper, that is, at the point A (the figures being chlorine 3·82, 4 hours' oxygen 4·12, albumenoid ammonia ·78), it is a simple matter to calculate out what proportion of

TABLE V (c).

ANALYSES OF SAMPLES TAKEN FROM INLET AND OUTLET OF SHAMNAGAR TANKS.

Date.	Origin.	Chlorine.	4 Hours' Oxygen-value.	4 Hours' Oxygen-value after clarification.	Colloid Organic.	3 MINUTES' OXYGEN-VALUE. Before incubation.	3 MINUTES' OXYGEN-VALUE. After incubation.	NITROGEN. Saline and free.	NITROGEN. Albumenoid Ammonia.	NITROGEN. Nitric and Nitrous.	AMOUNT OF DISSOLVED OXY. LEFT, DILUTION 1 IN 10 WITH TAP WATER. After 24 hours.	AMOUNT OF DISSOLVED OXY. LEFT, DILUTION 1 IN 10 WITH TAP WATER. After 48 hours.	REMARKS.
7-12-09	Discharge pipe Tank I	4·0	3·31	1·82	1·49	1·06	1·21	5·77	·60	*Nil*	·34	·24	
7-12-09	Grit Chamber ,, I	3·8	4·17	2·67	1·50	1·13	1·35	5·20	·70	,,	·31	·22	
7-12-09	Discharge pipe ,, II	3·6	3·22	1·91	1·31	1·06	1·21	2·77	·67	,,	·32	·19	
7-12-09	Grit Chamber ,, II	3·6	3·69	2·08	1·61	1·28	1·43	2·15	·72	,,	·29	·11	
14-12-09	Discharge pipe ,, I	4·0	3·24	1·67	1·57	1·13	1·19	3·35	·64	,,	·32	·19	
14-12-09	Grit Chamber ,, I	4·0	4·09	2·19	1·90	1·73	2·03	3·38	·72	,,	·29	·09	
14-12-09	Discharge pipe ,, II	3·8	3·14	1·67	1·47	·96	1·19	3·97	·56	,,	·32	·22	
14-12-09	Grit Chamber ,, II	3·8	4·29	2·47	1·82	1·67	1·91	2·77	·85	,,	·26	*Nil*	
21-12-09	Discharge pipe ,, I	4·0	3·70	1·70	2·00	1·09	1·33	4·90	·66	,,	·33	·19	
21-12-09	Grit Chamber ,, I	3·8	4·40	2·40	2·00	1·57	1·69	3·38	·83	,,	·31	·05	
21-12-09	Discharge pipe ,, II	3·6	3·50	1·50	2·00	·97	1·33	3·38	·64	,,	·34	·21	
21-12-09	Grit Chamber ,, II	3·8	4·20	2·50	1·70	1·45	1·69	2·77	·88	,,	·31	·05	
3-1-10	Discharge pipe ,, I	3·8	3·41	1·12	1·99	1·40	1·50	6·93	·67	,,	·29	·10	
3-1-10	Grit Chamber ,, I	3·8	4·11	1·62	2·49	1·46	1·60	5·77	·80	,,	·16	*Nil*	
3-1-10	Discharge pipe ,, II	4·0	3·37	1·55	1·82	1·59	1·70	3·98	·63	,,	·34	·12	
3-1-10	Grit Chamber ,, II	4·0	4·00	1·68	2·32	1·78	1·80	2·77	·76	,,	·19	*Nil*	
Average of Grit Chamber sample ...		**3·82**	**4·12**	**2·20**	**1·9**	**1·50**	**1·69**	**3·52**	**·78**	,,	**·26**	**·065**	
,, Discharge pipe ,, ...		**3·85**	**3·36**	**1·65**	**1·71**	**1·15**	**1·33**	**4·10**	**·63**	,,	**·32**	**·18**	
Percentage of purification ...		...	**18·8%**	...	...	...	...	...	**19·2%**	...	...	...	

	Chlorine.	4 Hours' Oxygen-value.	Albumenoid Ammonia.
Estimated strength of sewage entering these latrine (about 7½ gallons per user)	4	16	4·5
Average of Discharge pipe effluent	3·85	3·36	·63
Total percentage of purification ...	...	79 %	86%
		of which 74·25% is accomplished in Grit Chamber and 4·75% in tank.	of which 82·66% is accomplished in Grit Chamber and 3·33% in tank.

the total purification is carried out in the tank. In this case only 4·75%, out of 79% total purification on the 4 hours' oxygen figure, and 3·3% out of 86% on the albumenoid ammonia figure is brought about in the tank. The remainder must obviously have occurred in the grit chamber. These figures are extremely interesting and still further demonstrate the efficiency and the extent of the action in the grit chamber. The total nitrogen figures, in the sludge, by weight of dry residue, are inlet 2·75%, outlet 2·00%.

Analysis of the grit chamber fœces, obtained from the Shamnagar installation, show that it is somewhat different from others, and cannot be taken as a type on account of the peculiar conditions in the grit chamber, brought about by the presence of jute fibre; consequently similar analyses were carried out in 3 or 4 other installations of identically the same design, in which there was no jute. Table V (*d*) gives the results of these analyses. They agree to a very large extent with the results obtained at Shamnagar, but it will be observed that in these instances the amount of purification in the tank proper is distinctly higher than that in the Shamnagar tank, the sewage coming into the tank being distinctly stronger. These figures should be carefully compared with those in Table No. V (*c*). This second series probably more nearly represents the usual state of affairs, the strength of the sewage entering the tank being very nearly the same as our experimental sewage *partially mixed.* The very high saline ammonia figure in these samples should be observed; this can only be due to the extra ammonia added to the sewage in the grit chamber from the breaking up of the masses of fœces. The percentage purification figures given at the foot of the table are important, and it

should be observed that in these the tank itself is doing a larger share of the work than was the case at Shamnagar.

One point, however, is extremely well demonstrated, namely, *that the less action there is in the grit chamber, the more is done in the tank.* This, after all, seems a natural proposition, for if 70% of the easily broken down material is acted on in the grit chamber, it stands to reason that the remaining 30%, which have resisted the action for weeks and possibly months, may not change very readily in the tank, though the action may be of a different nature.

We do not maintain, that, if a *homogeneous* sewage of the same dilution was introduced into this design of tank, the same quality of effluent would be obtained ; there would probably be some falling-off, by the elimination of the grit chamber action, but the study we have made on many installations, seems to show that the total purification, from start to finish, does not vary very much in different installations, although the amount of purification carried out by the tank proper and the grit chamber respectively may vary within certain limits.

There is one practical point which arises from this subject, namely, that for ordinary practice, when dealing with fresh sewage, if you design a grit chamber properly, there seems to be much less necessity for a large tank capacity, as a very large amount of purification would result even if the tank were absent. This, however, is hardly to be seriously put forward, for one never can be quite sure, what proportion of the total fœces of a community are solid, and it is quite possible that some accidental circumstance, such as the mango season, or taking into use the new season's rice, might alter the

general character of the sewage considerably. We have already shown that the tank is of a sort of second line of defence; if much unaltered organic matter escapes the action in the grit chamber, it is dealt with in the tank.

CHAPTER VI

THE OPTIMUM REST IN THE TANK.

IN Chapter III we made a statement that as the result of experiments a 3 days' rest in the tank for a 5-gallon sewage had given very satisfactory results. We will now discuss the evidence on which this statement is based. In the summer of 1906, a very interesting series of experiments was commenced by Dr. Fowler on the action observed in small model septic tanks, making use of a Winchester quarter bottle as the tank. Two such models were started up. To these a measured quantity of the experimental sewage manufactured at the Entally Depôt was added daily, the effluent that came over being analysed from time to time. In this particular experiment one bottle was inoculated with a sludge from a septic tank latrine and the other was not. The early analyses demonstrated the fact that the bottle that had been inoculated gave a superior effluent to the one that had not been so prepared, the effluent from this latter being distinctly more offensive in odour than that from the inoculated tank; as time went on, however, the quality of the two effluents became very similar. The following table gives

the results of this experiment with a 10-gallon sewage :—

TABLE VI (*a*).

DATE.	Chlorine.		4 Hours' Oxygen Value.	
	Tank I.	Tank II.	Tank I.	Tank II. (inoculated).
26-3-06	...	...	·48	1·09
28-3-06		.	(?)	1·65
29 3-06	...	...	3·19	2·44
30-3-06			2·87	2·07
32-3-06	6·6	6·4	3·79	3·27
2-4-06	6·4	6·4	3·29	2·82
3-4-06	6·6	6·4	3·64	3·83
4 4-06	6·0	5·8	3·24	3·20
5 4-c6	5·6	5·8	2·89	3 77
6-4-06	6·0	6·0	3·11	2·48
7-4-06	5·3	5·8	2·13	1·73
9-4-06	6·0	6·0	2·51	2·33
1c-4-06	6·6	6·4	3·04	3·24
Average	*6·1	6·1	3 07	2 96

* This chlorine figure in the water used for dilution was 4 pts. per 100,000.

Shortly after this the strength of the sewage was doubled. Experiments on these tanks were continued for something like three months, two small percolating filters being added. A careful scrutiny of the result obtained after the alteration of the strength of the sewage, has led one to believe, that, the experimental sewage at this time was not made according to the orders laid down, hence it is not considered desirable to give in detail these results, nor to base any important conclusions upon them, as there is strong suspicion that the conditions under which the experiments were carried out were not

always uniform. Owing to an accident these little models were spoilt just when they were giving excellent results and it became necessary to begin afresh. Consequently it was decided to extend the scope of the experiment somewhat and to slightly modify the arrangements; thus, instead of using Winchester quart bottles, four large car-boys were procured each

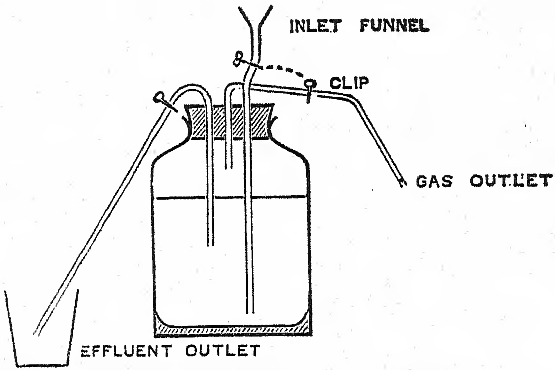


Fig. VI (*a*).

holding exactly 3 Winchester quarts a-piece. These were fitted up as regards inlet and outlet pipes in exactly the same way as Dr. Fowler's models, *vide* the Fig. VI (*a*); all were inoculated with septic tank sludge from a working installation, and a varying quantity of the same sewage was admitted to each bottle. The bottles were labelled tank I, tank II, tank III, etc. Into tank I one Winchester quart of crude sewage per diem was allowed to run very slowly; into tank II a bottle and a half was admitted; into tank III two bottles and into tank IV three bottles. Consequently it will be

observed that the period, during which the sewage remained in the tanks in each case, was—

In tank	I	3	days,
,, ,,	II	2	,,
,, ,,	III	36	hours, and
,, ,,	IV	a	day or 24 hours.

The object of the research was primarily to find out what was the optimum rest in the tank, for the sewage chosen, or in other words, which of these various tanks gave the best effluent. The experiment was commenced in October 1906.

At the same time as the tanks were started up, two small contact beds were constructed, as it seemed desirable to nitrify the various effluents and to ascertain if any difficulty in carrying out this process would be met with. Accordingly two zinc buckets were taken, ordinary half inch taps were soldered in the bottom so as to permit of draining away the effluent after contact. Each contained about ·6 of a cubic foot of material. At the bottom of the buckets about 2 inches of coarse material were placed to facilitate draining, the particles being between one and two inches in size; but the bulk of the material used was very fine; it would pass ⅛th of an inch mesh, but all that passed 1-16th of an inch was rejected. Both primary and secondary tanks (contact bed I and contact bed II) were filled up with the same material. The method of working was as follows:—

A mixture of the effluents from tanks I, II, III and IV were put on to contact bed No. I at 10 A.M.; at 2 P.M. the stopcock was opened and the contents were allowed to run direct to the contact bed No. II. The effluent was allowed to remain in contact bed No. II for

a period of 4 hours and was then allowed to flow away. Consequently the effluent had two periods of 4 hours' contact in each little bed, the material having 20 hours to aerate and recover. The total fluid capacity of each bed was about 1,400 c.c., or 1·4 litres.

The average results of the daily analysis of these tanks for October, November, December 1906 were as follows :—

TABLE VI (*b*)

Origin.	Chlorine.	4 Hours' Oxygen value.	Nitrogen.	
			Saline and free.	Albumenoid Ammonia.
Crude Sewage* ...	*8·9	26·64	2·30	5·94
Tank I	8·5	8·39	7·29	·95
,, II	7·7	9·07	6·42	1·12
,, III	7·3	10·26	5·94	1·24
,, IV	8·4	10·80	5·68	1·48

* At this time the water used for making the crude sewage contained 4 pts. per 100,000 of chlorine.

In November 1906 I proceeded on furlough and subsequently took up an appointment in Madras, returning to Bengal only in August 1909. It was gratifying to find that during the whole of this time, a period of nearly 3 years, these model septic tanks and contact beds had been worked on the lines laid down at the commencement, without, as far as I can ascertain, a day's intermission. Consequently, sufficient time having elapsed for the models to thoroughly ripen, the results

of investigations on the various effluents may be looked upon as those likely to be obtained from any septic tank installation, that is steadily and regularly worked, for a long period of time, with a similar sewage, with the proviso that these to be discussed were obtained from small laboratory models.

In the early part of Chapter IV, when discussing the subject of the quality and the strength of the sewage admitted to the usual septic tank, a reference was made to what appears to be an error on the part of our laboratory staff in the manufacture of the crude sewage used for experimental purposes. Only after a very considerable number of analyses had been completed in this investigation, was it discovered, that, the crude sewage of 1909 was of very different strength to that used in 1906. The explanation has already been given, namely, that our sweeper staff had, in the course of many months, gradually become negligent in the way in which the hard masses of fœces were broken up. Hence the crude sewage utilised for the following work cannot be called a true 5-gallon sewage. It is a 5-gallon sewage minus the hard masses; but as the error in manufacturing is exactly what would take place in an ordinary latrine, the results obtained are of considerable practical value.

A preliminary set of investigations were undertaken, making use of two simple tests only, *viz.*, the amount of oxidisable matter as shown by the oxygen absorption in four hours from an acid solution by potassium permanganate and the chlorine estimation. Table No. VI (*c*) gives the results obtained from crude sewage, the effluents of 4 tanks and the two contact beds.

The tests carried out on the nitrified effluent (that is, the effluent of contact beds I and II) were done with

TABLE VI (*c*).

DATE.	CRUDE.		TANK I.	TANK II.	TANK III.	TANK IV.	CONTACT BED I.	CONTACT BED II.
	4 Hours' Oxygen Test.	Chlorine.	4 Hours' Oxygen Test.	4 Hours' Oxygen Test.	4 Hours' Oxygen Test.	4 Hours' Oxygen Test.	4 Hours' Oxygen Test.	4 Hours' Oxygen Test.
7th August 1909	7·41	6·6	2·16	2·88	3·67	2·95	1·90	1·80
9th ,, ,, ...	7·81	6·6	2·29	3·33	2·50	2·08	1·66	1·04
10th ,, ,, ...	7·34	6·4	2·76	2·44	2·13	1·70	1·27	·85
11th ,, ,, ...	8·29	6·0	2·66	3·13	2·87	2·02	1·91	1·38
12th ,, ,, ...	11·97	6·0	2·72	3·13	4·07	4·49	2·17	1·76
13th ,, ,, ...	10·99	8·4	2·25	3·04	3·97	4·10	2·25	1·85
14th ,, ,, ...	11·56	8·4	2·04	2·45	2·86	4·76	1·90	1·22
16th ,, ,, ...	10·86	7·2	2·51	3·04	3·71	3·04	2·51	1·85
17th ,, ,, ...	8·31	7·8	2·08	2·59	3·63	4·28	2·20	1·29
18th ,, ,, ...	14·28	8·4	2·52	2·85	4·03	4·20	2·01	1·68
19th ,, ,, ...	16·64	6·8	2·24	3·20	3·52	5·36	2·25	1·20
20th ,, ,, ...	9·23	6·6	1·76	2·41	3·73	4·28	1·86	1·53
21st ,, ,, ...	9·04	6·8	1·81	2·10	2·71	3·51	1·81	1·50
23rd ,, ,, ...	17·50	7·4	2·89	3·15	4·47	4·21	1·84	1·18
24th ,, ,, ...	13·20	7·0	5·00	6·80	6·40	7·00	2·80	2·20
25th ,, ,, ...	9·74	7·2	2·15	2·35	2·77	3·89	1·53	1·02
26th ,, ,, ...	8·49	6·8	2·04	2·04	2·90	2·90	1·07	·75
27th ,, ,, ...	11·57	8·8	2·21	4·42	4·52	6·94	1·79	1·26
30th ,, ,, ...	11·17	6·0	2·79	2·79	3·97	4·41	1·31	1·03
31st ,, ,, ...	9·53	6·6	3·35	3·89	4·16	4·83	1·07	·80
Average ...	**10·75**	**7·1**	**2·51**	**3·10**	**3·63**	**4·05**	**1·85**	**1·32**

the use of urea in order to eliminate the nitrites from the estimation. The average figures given from 20 comparative estimations show that of the 4 tanks, tank No. I is decidedly the best, and it gives about 75 per cent. of purification calculated on the 4 hours' oxygen figure of the crude sewage; this is a distinctly good result. Tank No. IV gives the worst result. Contact beds Nos. I and II were fed with a mixture of all the four effluents and show a very considerable purification. The chlorine figures are used simply as checks; they do not vary in any of the effluents. Further remark need not be made on these results as the subsequent more detailed analyses are of greater importance.

TABLE VI (*d*).

Entally Crude Sewage.

Date.	Chlorine.	4 Hours' Oxygen Test.	Nitrogen.	
			Saline and Free Ammon.	Albumen-oid. Ammon.
28th Sept. 1909	7·0	12·27	2·84	3·02
29th ,, ,, ...	6·8	10·15	1·97	2·31
30th ,, ,, ...	6·8	10·38	1·97	2·33
2nd Oct. ,, ...	7·2	10·88	2·71	2·50
4th ,, ,, ...	6·8	10·36	2·03	2·97
Average	**6·9**	**10·80**	**2·30**	**2·49**

TABLE VI (*e*).

Date	Tank I. 4 Hours' Oxygen Test.	Tank I. Chlorine.	Tank I. Nitrogen. Saline and Free Ammoniacal.	Tank I. Nitrogen. Albumenoid Ammoniacal.	Tank II. 4 Hours' Oxygen Test.	Tank II. Chlorine.	Tank II. Nitrogen. Saline and Free Ammoniacal.	Tank II. Nitrogen. Albumenoid Ammoniacal.	Tank III. 4 Hours' Oxygen Test.	Tank III. Chlorine.	Tank III. Nitrogen. Saline and Free Ammoniacal.	Tank III. Nitrogen. Albumenoid Ammoniacal.	Tank IV. 4 Hours' Oxygen Test.	Tank IV. Chlorine.	Tank IV. Nitrogen. Saline and Free Ammoniacal.	Tank IV. Nitrogen. Albumenoid Ammoniacal.
4th Sept. 1909 ...	...	...	...	...	...	...	...	...	5·57	6·4	8·00	·76	5·65	6·4	6·93	·80
6th ,, ,, ...	2·67	6·6	8·66	·63	3·74	6·6	8·00	·66	...	...	...	...	...	...	...	...
8th ,, ,, ...	...	...	...	...	...	...	...	...	2·69	6·4	4·73	·42	3·00	6·4	4·00	·60
9th ,, ,, ...	2·58	7·4	5·77	·33	2·72	7·4	5·70	·41	...	...	...	...	...	...	...	...
10th ,, ,, ...	...	...	...	...	...	...	...	...	3·25	6·8	6·93	·53	4·00	6·8	6·50	·61
11th ,, ,, ...	2·34	6·8	8·00	·28	3·95	6·8	7·43	·35	...	...	...	...	...	...	...	...
13th ,, ,, ...	...	...	...	...	...	...	...	...	2·60	6·0	6·50	·37	3·31	6·0	6·12	·66
14th ,, ,, ...	2·64	6·8	8·00	·33	2·89	6·8	6·93	·41	...	...	...	...	...	...	...	...
15th ,, ,, ...	...	...	...	...	...	...	...	...	5·26	7·6	5·73	·68	5·45	7·6	5·20	1·03
23rd ,, ,, ...	2·04	6·6	8·67	·26	2·61	6·6	8·00	·44	...	...	...	...	...	...	...	...
Average ...	**2·45**	**6·8**	**7·82**	**·36**	**3·18**	**6·85**	**7·21**	**·45**	**3·86**	**6·6**	**6·37**	**·55**	**4·28**	**6·6**	**5·75**	**·74**
	Rest in Tank 3 days.				Rest in Tank 2 days.				Rest in Tank 36 hours.				Rest in Tank one day or 24 hours.			

TABLE VI (*f*).

DATE.	Mixture of Effluents from Tanks 1, 2, 3 & 4. 4 Hrs.' Oxy. value.	CONTACT BED No. I. 4 Hours' Oxygen value.	Chlorine.	NITROGEN. Saline & Free Ammoniacal.	Albumenoid Ammoniacal.	Nitrous & Nitric.	CONTACT BED No. II. 4 Hours' Oxygen value.	Chlorine.	NITROGEN. Saline & Free Ammoniacal.	Albumenoid Ammoniacal.	Nitrous & Nitric.
15th Sept. 1909	3·45	1·95	7·0	1·04	·24	·85	1·33	7·0	·42	·14	1·66
16th ,, ,,	3·11	1·11	6·8	1·28	·18	1·16	·70	6·8	·32	·12	2·65
19th ,, ,,	5·26	1·35	6·6	1·73	·25	·61	·70	6 6	1·11	·17	1·10
21st ,, ,,	3·42	1·14	6·8	·83	·22	1·06	·69	6·8	·32	·10	3·15
23rd ,, ,,	3·07	1·77	7·0	·64	·22	1·33	1·09	7·0	·25	·16	2·20
Average ..	3·38	1·47	6·8	1·10	·22	1·00	·92	6·8	·48	·14	2·15

The quantity passed through the contact beds is 1,400 cubic centimetres, or about a litre and a half; this is about ·3 of a gallon. The quantity of material in the beds is about ·6 of a cubic foot; that is, about 17 litres.

TABLE VI (*g*).

Comparison of Average Results.

	Col. 1. 4 HOURS' OXYGEN TEST. Actual.	Percentage purification on crude figure.	Col. 2. Chlorine.	NITROGEN. Col. 3. Saline Ammoniacal.	Col. 4. Albumen. Ammoniacal. Actual.	Percentage purification on crude figure.	Col. 5. Nitrous and Nitric.
Crude sewage ...	10·80	......	6·9	2·30	2·49	......	...
Tank No. 4	4·28	60·0 %	6·6	5·75	·74	70·2 %	...
Tank No. 3 ...	3·86	64·2 %	6·6	6·37	·55	77 9 %	...
Tank No. 2 ...	3·18	70·5 %	6·8	7·21	·45	81·9 %	...
Tank No. 1 ...	2·45	77·3 %	6·8	7·82	·36	85 5 %	..
Contact Bed No. 1	1·47	86·4 %	6 8	1·10	·22	91·1 %	1·00
Contact Bed No. 2	·92	90·5 %	6·8	·48	·14	94·4 %	2·15

Contact Bed No. 1 gives 56·5% of purification on the average 4 Hours' Oxygen figure of mixture of effluents put into the bed. The figure is 3·38 part per 100,000.

Contact Bed No. II gives 72·8% on the same basis.

Tables VI (*d*) (*e*) (*f*) give a more detailed analysis of the crude sewage, the effluents of the 4 models and of those of the 2 contact beds. In each case 5 full analyses were carried out. Table VI (*g*) gives a statement of the averages of the results obtained. It is not necessary to deal with any single analysis, but attention should be directed to Table IV (*g*), which gives in graphic form the epitome of the results obtained.

In column 1 the 4 hours' oxygen figures and the percentage purification calculated on the 4 hours' oxygen of the crude sewage are set forth. The steady falling-off in oxidisable matter in the effluents should be observed in the figures as they are set down. Of the 4 tanks it will be observed that tank No. I (that is the one with 3 days' rest) gives not only the best result, but an extraordinary amount of purification; no less than 77·3 per cent. of the oxidisable matter has been broken down during the period of rest in the tank. The contact beds Nos. I and II further reduce the amount of easily oxidisable matter as well as nitrify a great deal of the saline ammonia. The final effluent from contact bed No. II having 90 per cent. of its oxidisable matter rendered innocuous.

In column 3 the saline ammonia figures are of great interest. Even with a short rest in the tank as 24 hours the saline ammonia is more than double the amount that was present in the crude sewage. In tank No. I the saline ammonia figure has reached as much as 7·82 parts per 100,000; of this amount the contact beds nitrify all but ·48 parts per 100,000. The albumenoid ammonia figures demonstrate the great activity of the tanks. Even with only a 24 hours' rest the 70 per cent. of the albumenoid ammonia has been converted into saline. Considering the strength of the sewage, this is a very satisfactory result. In tank No. I, where the period of

rest is 3 days, 85 per cent. of the total albumenoid ammonia is so changed.

The amount of nitrification carried out by the materials in the contact beds is also very considerable, as will be observed from the above figures, *vide* column 5.

These results may therefore be taken to be about the maximum obtainable with this very simple apparatus dealing with so concentrated a sewage. In all cases it will be observed that tank No. I (one with 3 days' rest) is superior to others. A further analysis was made of the effluent from contact beds I and II when they are fed with the effluent of tank No. I only. The figures showed only a slight improvement on those given above.

Putrescibility Test.

The putrescibility of the various effluents was determined in the usual way. Five separate incubator tests of crude sewage, effluents of tanks Nos. I, II, III and IV, and of the two contact beds were carried out. The figures are given in Table VI (*h*).

Table VI (*h*).

Putrescibility Test.

Samples.	3 Minutes' Oxygen Test. Before Incubation.	3 Minutes' Oxygen Test. After Incubation.	
Contact Bed No. II (1st series) ...	·11	·15	
,, ,, II (2nd ,,) ...	·12	·16	
,, ,, II (3rd ,,) ...	·16	·16	
,, ,, II (4th ,,) ...	·11	·15	
,, ,, II (5th ,,) ...	·13	·14	
Average	**·12**	**·15**	Difference ·03

TABLE VI (*h*).—(*Contd.*)

Samples.	3 Minutes' Oxygen Test. Before Incubation.	After Incubation.	
Contact Bed No. I (1st series) ...	·21	·30	
,, ,, I (2nd ,,) ...	·24	·34	
,, ,, I (3rd ,,) ...	·32	·44	
,, ,, I (4th ,,) ...	·22	·32	
,, ,, I (5th ,,) ...	·26	·29	
AVERAGE ...	**·25**	**·36**	Difference ·11
Tank No. I (1st series) ...	·43	·45	
,, ,, I (2nd ,,) ...	·71	·89	
,, ,, I (3rd ,,) ...	·65	·89	
,, ,, I (4th ,,) ...	·56	·78	
,, ,, I (5th ,,) ...	·77	·89	
AVERAGE ...	**·62**	**·78**	Difference ·16
Tank No. II (1st series) ...	·54	·91	
,, ,, II (2nd ,,) ...	·95	1·01	
,, ,, II (3rd ,,) ...	·97	1·01	
,, ,, II (4th ,,) ...	·78	1·09	
,, ,, II (5th ,,) ...	1·03	1·32	
AVERAGE ...	**·85**	**1·07**	Difference ·22
Tank No. III (1st series) ...	·79	1·22	
,, ,, III (2nd ,,) ...	1·07	1·56	
,, ,, III (3rd ,,) ...	1·29	1·34	
,, ,, III (4th ,,) ...	1·01	1·56	
,, ,, III (5th ,,) ...	1·16	1·47	
AVERAGE ...	**1·06**	**1·43**	Difference ·37
Tank No. IV (1st series) ...	·97	1·83	
,, ,, IV (2nd ,,) ...	1·19	2·01	
,, ,, IV (3rd ,,) ...	1·54	2·01	
,, ,, IV (4th ,,) ...	1·23	2·03	
,, ,, IV (5th ,,) ...	1·29	1·62	
AVERAGE ...	**1·24**	**1·90**	Difference ·64

Crude Sewage.

DATE.	4 Hours' Oxygen Test.	3 MINUTES' OXYGEN TEST. Before Incubation.	3 MINUTES' OXYGEN TEST. After Incubation.	
10th Sept. 1909	11·25	3·11	6·13	
11th " "	13·33	4·33	6·13	
13th " "	13·72	3·96	5·11	
22nd " "	10·97	3·45	5·93	
24th " "	9·25	2·84	4·56	
AVERAGE ...	**11·70**	**8·54**	**5·57**	Difference 2·03

The crude sewage is, as one would expect, naturally very putrescible and the difference between the 3 minutes' oxygen test before and after incubation is as much as 2 parts per 100,000; no hydrogen sulphide was, however, found after incubation. There is a steady falling-off in the difference between these two sets of figures the longer the sewage remains in the tank, so that the difference in the case of tank No. I is quite small. It is still further reduced by the contact beds, so that in the final result it is less than ·03 parts per 100,000. From considerable experience of this test our opinion as to its value has diminished.

ESTIMATION OF COLLOIDS.

The usual estimation for colloid material already described in Chapter IV was carried out on the crude sewage, the effluents of the 4 tanks and of the two contact beds. The results are given in Table VI (*j*) below.

TABLE VI (*j*).

Clarification Test.

Date.	Contact Bed II.		Contact Bed I.		Tank I.		Tank II.		Tank III.		Tank IV.		Crude Sewage.	
	Before clarification.	After clarification.	Before clarification.	After clarification.	Before clarification.	After clarification.	Before clarification.	After clarification.	Before clarification.	After clarification.	Before clarification.	After clarification.	Before clarification.	After clarification.
1st October 1919 ...	·76	·63	1·28	1·14	1·77	1·39	2·28	1·52	3·04	1·64	3·16	1·77	7·34	2·15
4th ,, ,, ...	·58	·58	1·57	1·29	2·73	1·44	4·17	2·59	4·17	2·59	4·39	2·73	10·36	3·02
5th ,, ,, ...	1·39	1·32	1·55	1·47	2·32	1·55	2·87	1·86	3·02	2·01	3·72	2·09	10·16	2·17
6th ,, ,, ...	·93	·80	2·00	1·87	2·40	2·13	2·53	2·13	3·07	2·25	3·47	2·40	14·25	3·33
8th ,, ,, ...	·53	·43	1·05	·95	2·74	1·26	3·16	1·37	4·95	1·68	5·15	1·76	14·84	1·89
AVERAGE ...	**·84**	**·75**	**1·49**	**1·34**	**2·39**	**1·55**	**3·00**	**1·89**	**3·08**	**2·03**	**3·98**	**2·15**	**11·39**	**2·51**
Colloids present ...	**·09**		**·15**		**·84**		**1·11**		**1·05**		**1·83**		**8 88**	

These figures are the 4 Hours' Oxygen absorption from Potassium Permanganate.

Contact Bed I and Contact Bed II are better than usual because tank I effluent *only* was put on to the beds.

It will be observed that about 75 per cent. of the total oxidisable matter in the crude sewage is colloid in nature. After treatment in any of the septic tanks a great deal of this has disappeared, and after the aerobic treatment in the contact beds a still further falling-off is observed, so that the amount left in the effluent from contact bed II is only ·09 parts per 100,000. Without entering into a long discussion as to what has become of these colloids, it may just briefly be stated, that, if they are simply separated out mechanically, they must have settled down at the bottom of the tanks in the form of sludge; consequently after a period of three years' working, these tanks, which it should be remembered are only bottles, would be mostly filled with this material. As a matter of fact, there is less than 2 inches of sludge at the bottom of each and this certainly does not present an appearance of colloid material. There is practically no doubt that by far the majority of these colloids have been changed, by the action of the anaerobic organisms or enzymes in the septic tanks, into crystalloid bodies. Even after so short a rest in the tank as 24 hours' about 70 per cent. of the colloids have disappeared. Further, it will be observed, that the longer the effluent remains in the septic tank, the more colloids are changed, and that the effluent from tank No. I contains a very small amount of such bodies.

Absorption of dissolved oxygen.

A mixture of 1 part of sewage or effluent to 9 of water is made and is allowed to stand for 24 and 48 hours. The quantity of oxygen dissolved in the water of

which the mixture is made, is estimated in the usual way by the manganous chloride method; the amount of oxygen remaining in the mixture after 24 or 48 hours is also similarly estimated. The falling-off in the amount of oxygen represents the amount absorbed by the oxidisable matter in the effluent or sewage which has been added to the water. The results are given in Table V (*k*), p. 77.

It will be observed that in the case of the mixture of the crude sewage no oxygen at all remained after 24 hours. In tank No. IV no oxygen remained after 48 hours and very little indeed after 24 hours. In the case of tank No. III no oxygen remained after 48 hours and no great quantity after 24 hours. Tanks Nos. I and II show that the falling-off in the oxygen present in the water, though considerable in quantity, is nothing like as much as in the case of tank No. IV. One may, therefore, conclude that effluent from tank No. I is in a very much more suitable condition to be discharged into any stream than that of tank No. IV. This test demonstrates this fact much more clearly than the analyses given previously. On comparing the results obtained with this test in the case of effluent from contact beds, it will be observed that the figures show that the second contact bed does not greatly lessen the amount of "oxygen seizing" matter in the effluent.

Nitrification test.

Five series of experiments were conducted with crude sewage; the effluents of the 4 tanks on the lines already described, namely, a mixture of the effluents and water, was allowed to stand in Winchester quarts half full; the mixture was shaken up daily and tested for

TABLE VI (*k*).

Absorption of dissolved Oxygen.

DATE.	**Contact Bed II.** Diluted with tap water (1 in 10).			**Contact Bed I.** Diluted with tap water (1 in 10).			**Tank I.** Diluted with tap water (1 in 10).			**Tank II.** Diluted with tap water (1 in 10).			**Tank III.** Diluted with tap water (1 in 10).			**Tank IV.** Diluted with tap water (1 in 10).			**Crude Sewage.** Diluted with tap water (1 in 10).		
	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs.' Oxy. from K_2MnO_4.	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs.' Oxy. from K_2MnO_4.	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs. Oxy. from K_2MnO_4.	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs.' Oxy. from K_2MnO_4.	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs.' Oxy. from K_2MnO_4.	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs.' Oxy. from K_2MnO_4.	Oxy. left after 24 hours.	Oxy. left after 48 hours.	4 hrs.' Oxy. from K_2MnO_4.
7th Oct. '09	·46	·43	...	·43	·41	...	·32	·23	...	25	·15	...	·16	*Nil*	...	·14	*Nil*	...	*Nil*	*Nil*	...
8th " "	·45	·42	...	·43	·41	...	·28	22	...	·23	·16	...	·16	*Nil*	...	·12	"	...	"	"	...
10th " "	·50	·48	...	·46	·44	...	·29	·18	...	·23	·13	...	·17	*Nil*	...	·14	"		"	"	...
11th " "	·49	·46	·64	·46	·43	1·04	·26	·19	2·72	·21	·14	3·6	·16	*Nil*	4·00	·13	"	4·72	"	"	12·48
12th " "	·49	·46	·80	·46	·44	1·20	·28	·19	3·20	·22	·15	4·16	·16	*Nil*	4·80	·12	"	5·52	"	"	12·64
Average ...	**·48**	**·45**	**·72**	**·45**	**·43**	**1·12**	**·28**	**·20**	**2·96**	**·23**	**·15**	**3·88**	**·16**	*Nil*	**4·40**	**·13**	*Nil*	**5·12**	*Nil*	*Nil*	**12·56**

The average dissolved oxygen in tap water in Calcutta is ·63 parts by weight per 100,000

the presence of nitrites. The results are given in Table VI (*l*).

TABLE VI (*l*).

Nitrification Test.

Experiment I ...	The effluent of Tank	I	took	7 days to nitrify.
	,, ,, ,, ,,	II	,,	8 ,, ,, ,,
	,, ,, ,, ,,	III	,,	9 ,, ,, ,,
	,, ,, ,, ,,	IV	,,	10 ,, ,, ,,
	,, Crude Sewage		,,	21 ,, ,, ,,
Experiment II ...	The effluent of Tank	I	,,	7 ,, ,, ,,
	,, ,, ,, ,,	II	,,	8 ,, ,, ,,
	,, ,, ,, ,,	III	,,	10 ,, ,, ,,
	,, ,, ,, ,,	IV	,,	11 ,, ,, ,,
	,, Crude Sewage		,,	23 ,, ,, ,,
Experiment III ...	The effluent of Tank	I	,,	5 ,, ,, ,,
	,, ,, ,, ,,	II	,,	6 ,, ,, ,,
	,, ,, ,, ,,	III	,,	7 ,, ,, ,,
	,, ,, ,, ,,	IV	,,	9 ,, ,, ,,
	,, Crude Sewage		,,	20 ,, ,, ,,
Experiment IV ...	The effluent of Tank	I	,,	5 ,, ,, ,,
	,, ,, ,, ,,	II	,,	6 ,, ,, ,,
	,, ,, ,, ,,	III	,,	7 ,, ,, ,,
	,, ,, ,, ,,	IV	,,	8 ,, ,, ,,
	,, Crude Sewage		,,	17 ,, ,, ,,
Experiment V ...	The effluent of Tank	I	,,	6 ,, ,, ,,
	,, ,, ,, ,,	II	,,	7 ,, ,, ,,
	,, ,, ,, ,,	III	,,	9 ,, ,, ,,
	,, ,, ,, ,,	IV	,,	9 ,, ,, ,,
	,, Crude Sewage		,,	20 ,, ,, ,,

It will be observed that a mixture of crude sewage and tap water (which contains roughly the same amount of oxidisable organic matter as the other mixtures of the series) took on an average 21 days to develop any nitrites, at the ordinary laboratory temperature; while the effluent, that had been submitted to the action of a septic tank for one day (tank No. IV) took 8, that for 2 or 3 days (tanks Nos. I and II) took about 7 and 6 respectively. Hence, by this simple experiment it is demonstrated that the effluent, that has been acted upon by anaerobic

organisms, in the septic tank is in a much more suitable condition for the action of nitrifying organisms present in water than one that has received no treatment. Further, the results show that the effluent of tank No. I which had a period of 3 days' rest in the tank is more readily nitrified than that of the other three.

After the discovery of the fact that a true 5-gallon sewage had not been used for these experiments, the defect was remedied and all 4 tanks were fed with the more concentrated sewage, for a period of a fortnight, to enable the tanks to accommodate themselves to the greater loads put on them. After this period analyses were again made. Table VI (*m*) gives the results obtained. The crude sewage made use of in these samples had a 4-hours oxygen value of about 20; this is not quite up to the average strength of a true 5-gallon sewage, but it is sufficiently near to show the difference produced in the tanks. It will be observed that the tanks still give a very remarkable amount of purification, though naturally not as much as was obtained in the former experiments when the sewage contained about half the amount of suspended matter. The percentage purification of tank No. I, calculated on 4 hours' oxygen figure, is still nearly 80 per cent., whilst that of tank No. IV is 60 per cent.

An important point to be observed in this table is that the increase in the amount of oxidisable matter in tanks Nos. II, III and IV is almost entirely colloidal in nature, the amount of crystalloid oxidisable matter being the same in all four. The saline ammonia figure as compared with table No. VI (*g*) shows an increase of about 20 per cent. due to the additional strength of the sewage, but it should be observed that the contact beds take on the work of nitrifying this extra ammonia without any apparent difficulty, for the effluents from the little beds contain the

TABLE VI (*m*).

RESULTS WITH MIXED SEWAGE.

DATE.	Origin.		Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	NITROGEN.			Amount of dissolved Oxygen left, dilution 1 in 10 with tap water.	
							Saline & free.	Albumenoid Ammonia.	Nitric & Nitrous.	After 24 Hours.	After 48 Hours.
	Crude	...	7	20 (about)							
9·2·10	Tank	4	7·6	7·57	4·12	3·45	6·15	1 69	*Nil*	*Nil*	*Nil*
9·2·10	,,	3	7·6	7 07	4·12	2 95	7·38	1·58	,,	·19	,,
8·2·10	,,	2	7 88	5·82	4·37	1·45	8·67	1·04	,,	·32	·04
8·2·10	,,	1	7·8	4 72	4·17	·55	9·45	·84	,,	37	·07
7·2·10	Contact bed	1	7·2	3 76	3·26	·50	1·73	·71	1·47	·55	·52
7·2·10	,,	2	7·2	2·47	2·13	·34	·44	·51	3·68	·58	·55
7·2·10	Mixture put into the contact bed	...	...	5·51	...	...	...	...	...	...	...

same amount of free ammonia as in the former experiments, the nitrates being proportionately increased. The albumenoid ammonia figures show a very considerable deterioration, hence it would appear that the more dilute sewage was nearer the optimum strength for septic action as regards the albumenoid ammonia figures.

From the foregoing analyses and the tests carried out on seven samples (crude sewage, 4 tank effluents, and two contact-bed effluents) the following conclusions appear to be legitimate :—

1. That of the 4 tank effluents, that derived from tank No. I, which has a period of rest in the tank of 3 days, is in every respect superior to any of the others. Further, that the quality of the effluents from the 4 tanks varies with the length of the rest of the sewage in the tank, so that not only is the effluent of tank No. I the best, but that of tank No. IV the worst.
2. That the action of the contact beds both in nitrifying the ammonia and in the removal of other material from the sewage renders the effluent a thoroughly satisfactory one for passing into any river or stream.
3. That with comparative simple arrangements a very great amount of purification can be obtained even in a very concentrated sewage.

In connection with these conclusions there are a few points that call for a little discussion.

From these results it might be argued that if larger tanks were provided and a longer period of rest in the tank was allowed, a still higher degree of purification would have been obtained. This proposition is probably correct within certain limits, for it appears to be almost

impossible to "over-septicize" a vegetarian sewage in the tropics, because Hydrogen sulphide is not easily formed. At the time the experiments were started (Oct. 1906) it was thought that 3 days' rest in the tank would be about the economic limit, and experience has confirmed this opinion, the purification obtained by this size of tank being very great. On the other hand, from an economical point of view a further increase of tank capacity is not to be desired. In designing septic tank installations the object should always be to get a maximum of purification with the minimum of expense. Large tanks mean heavier cost of construction, and what is sometimes of greater importance, more land.

An additional reason why a tank capacity of 15 gallons per user (5 gallons per head with 3 days' rest) is the most convenient, is that this size gives just the right amount of space for adequate seat accommodation for the population for whom the latrine is constructed, provided that the length, breadth and depth are determined by the considerations given in chapter III.

Another query may occur to the mind of the reader, *viz.*, when the action of the septic tank can bring about something like 60 per cent. of purification, on the very concentrated sewage, with a 24-hours rest, is it economical to double or treble the size of the tank in order to obtain an additional 10 or 15 per cent.? The answer appears to be, that it is economical and safer to provide fairly large tanks, in spite of the great rapidity of the early breaking-down process. The foregoing results show distinctly that the further the septic action has gone, the easier is the nitrification process. Filters or aerobic arrangements in the tropics are, as a rule, much greater sources of nuisance than the septic tanks themselves. When dealing with the subject of filters, we

shall study their various disadvantages and limitations, the difficulty of obtaining a suitable material and adequate supervision are amongst the number of these. Furthermore, in many places where these installations are required, land is extremely valuable; consequently it is obviously economical to carry the septic action as far as possible in the tank in order to be able to provide comparatively small filters.

A sound chemical reason for providing tank capacity at the above rate appears to be, the importance of getting rid of as much of the colloidal material as possible from the effluent. Colloid material causes endless trouble in the aerobic process; the analyses of the effluents obtained when a concentrated sewage was used (Table VI (*h*)) show, that the disappearance of colloids is slow, and that time is necessary for the change.

A practical argument in favour of keeping the tank of a large size is, that, with smaller tanks the greater the variation in the inflow, the greater the disturbance in the sedimentation action in the body of the tank. We have already remarked that this design of latrine is used irregularly. If the tank capacity is to be cut down much below what is proposed, currents will be set up, settlement will not take place, and it will be extremely difficult to insure that, the sewage coming in during a rush, really gets the rest in the tank that it is supposed to, though the average rest for 24 hours may be correct. We therefore consider that for chemical, engineering and economical reasons a large tank capacity is distinctly desirable; there does not appear to be any decided advantage in increasing it above 15 gallons per user per diem, with a dilution of 5 gallons per head.

Before finally closing this chapter, it may be interesting to compare the results given by these little models

with those obtained from larger installations. Of course, in Chapters IV and V many detailed analyses of actual installations are given, particularly those of Shamnagar Jute Mill, Clive Jute Mill, Standard Jute Mill and Kanchrapara Workshops, but it would be interesting to show whether the results obtained in the majority of working installations agree with those obtained in the laboratory models. The following Table VI (*n*) demonstrates the fact that the two sets of figures coincide very largely, provided latrines chosen are not seriously over-worked beyond the capacity for which they are designed.

Of course, it must be remembered that the results obtained from the model septic tanks and those obtained from the working installations are not strictly comparable; in the former there is nothing that can be said to correspond with the grit chamber, except the somewhat fortunate carelessness of our staff in omitting to mix the fœcal masses with the water. Still the similarity between the two sets of figures is remarkable.

TABLE VI (*n*).

CHEMICAL ANALYSIS OF EFFLUENT FROM THE SEPTIC TANK.

	Chlorides.	4 Hours' Oxygen.	Dissolved Oxygen remaining. Solution 1 in 10.		Nitrates.	Remarks on Physical character and sterilization of effluent.
			24 Hours.	48 Hours.		
Tittagurh Jute Mill—						
Unfiltered ..	6	2·9	·20	*Nil.*		
Filtered ...	6	1·5	·40	·15	Trace.	
Standard Jute Mill—						
Unfiltered ...	6·4	3·4	·22	*Nil.*		
Filtered ...	6·4	1·8	·39	·19	Fair quantity.	
Dalhousie Jute Mill—						
Unfiltered ...	6·7	3·7	·25	·1		
Filtered ..	6·8	1·7	·45	·21	Fair quantity.	

CHAPTER VII.

ANALYSIS OF SLUDGE AND GASES GIVEN OFF.

ALTHOUGH by far the most interesting and probably the most important action that goes on in a septic tank is the mineralization of the nitrogen element, still it must not be forgotten that this is only one of a very large number of such changes. Many of the other actions are ill-defined and up to the present time ill-understood, but there is one, which is at any rate extremely apparent, and that is, the breaking up of the cellulose and carbo-hydrate compounds into marsh gas, hydrogen and carbon dioxide. Before proceeding with the subject, it must be stated that the bulk of the work to be described in this chapter was done when Dr. Fowler was with us in India and quite a large proportion was actually carried out by himself. Most of this work is taken from section "C" of his report on Septic Tanks in Bengal; a certain proportion of this was, however, done after he had left this country, although the figures were forwarded to him and appear in his work. Any reader requiring more exhaustive information on this subject than it is proposed to give in this work should consult Dr. Fowler's report. This subject has recently not received a very large share of attention, because it is of comparatively small practical importance,

that is to say, it does not affect the design of tanks.

Analysis of the Entally crude sewage as regards its carbon, nitrogen, sulphur was made the result is given in table following :—

Total organic carbon	..	27·6
Total organic nitrogen	..	8·25 (with urine).
Total organic sulphur	..	·52

These figures were obtained from a residue made by evaporating down the ordinary 5-gallon Entally crude sewage. The total nitrogen figures are not always the same in different samples because the amount of urine present varies a little. If fœces only are taken, the results are very uniform. The figures given in Table V (*a*) are really much more important than the above, because they deal with fœces only; the total nitrogen in dried fœces obtained from a vegetarian populace is about 5·6% of the dried residue. This figure is confirmed by very many estimations which have been made by Capt. McCay. If the fœcal discharges and the *whole of the urine in 24 hours* of an individual on ordinary diet be evaporated to dryness, the nitrogen figure in the dried residue would be about 12%. An artificial European sewage was manufactured by myself on two occasions, the dilution of which was practically unknown, but the total urine of 24 hours was added. The results of analysis give : total carbon 25·92, total nitrogen 21·2, sulphur 1·99. The great increase in the total nitrogen and sulphur over the Entally sewage should be noted. These results, though too scanty to draw any important conclusion from, agree with the exhaustive researches of Capt. McCay, I.M.S.

In a study of the fermentation of cellulose, the analysis of gas obtained from large septic tanks was

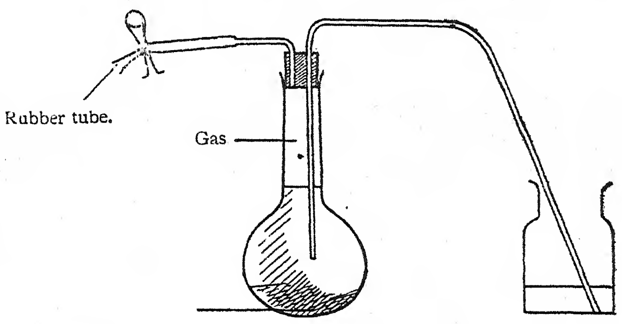


Fig. VII (*a*).—Apparatus for collecting gas.

carried out; a small apparatus, shown in fig. VII (*a*), was also set up to collect the gas evolved from any given material, such as sludge, fœces or sewage. The description and the use of the apparatus is quoted from Dr. Fowler's report :—

"The general method, except where otherwise stated, for observing the quantity of gas evolved and collecting it for analysis consisted in placing a known quantity of the sample in a bottle or flask, which was completely filled with the sample in the case of sewage, or with water (generally boiled to drive out dissolved gases) in the case of sludge samples and closed by a double-bored India-rubber stopper. Through one hole in the stopper a tube was passed to about two-thirds of the depth of the bottle and bent twice at right angles; as the gas was evolved, the liquid was forced out through this tube, and could be collected and measured, the volume being equal to the volume of the gas evolved. Through the

other hole of the stopper a tube passed just to the under surface of the stopper. This tube was bent at right angles and closed by a piece of India-rubber tubing and a screw-clip. The gas could thus be withdrawn through this tube for analysis, being replaced by water drawn in simultaneously through the other tube. In some cases this tube was omitted and the gas collected by opening the bottle or flask under a funnel filled with, and immersed in brine. The stem of the funnel was closed by India-rubber tubing and a screw-clip, and could thus be attached to the gas-measuring burette."

"By this simple method the fermentation took place practically under atmospheric pressure throughout, and in general little or no solid matter, which was the chief source of the gas evolved, passed out of the bottle."

The gases of various samples were analysed in the usual way and the results are given in the Table VII (*b*).

It will be observed from the composition of the gases that they are due to the breaking up of carbo-hydrate bodies. In the work done by Dr. Fowler on the subject whilst in Bengal he discussed two points: (1) the amount of cellulose and similar substances that is actually split up, and converted into gas in a given time by fermentation under anaerobic action; and (2) to decide if any of the nitrogen in the proteid bodies could be recovered as free nitrogen from the sewage. The conclusions arrived at by him on these points are :—

(1) "The decomposition of organic matter in the deposit found in the main tank, and its conversion into gas is a process extending over a long time, but however long the deposit remains in the tank, it does not appear possible to get rid of more than at most 50% of the organic matter in this way. The remaining 50% together

TABLE V (d).

ANALYSES OF SAMPLES TAKEN FROM INLET AND OUTLET OF TANKS.

Date.	Origin.	Chlorine.	4 Hours' Oxy.-value.	4 Hours Oxygen-value after clarification.	Colloid Organic.	Nitrogen. Saline and free.	Nitrogen. Albumenoid Ammonia.	Nitrogen. Nitric and Nitrous.	Amount of dissolved Oxygen left, dilution 1 in 10 with tap water. After 24 hours.	Amount of dissolved Oxygen left, dilution 1 in 10 with tap water. After 48 hours.	Remarks.
24-3-10	Kanchrapara Tank I Grit Chamber ...	5·0	5·71	2·69	3·02	8·67	1·00	*Nil*	*Nil*	*Nil*	
24-3-10	Kanchrapara Tank I Discharge pipe ...	5·0	4·17	1·84	2·33	9·45	·57	,,	·15	,,	
24-3-10	Kanchrapara Tank II Grit Chamber ...	5·2	11·16	2·82	8·34	8·00	1·15	,,	*Nil*	,,	
24-3-10	Kanchrapara Tank II Discharge pipe ...	5·2	5·03	2·08	2·95	8·67	·62	,,	·14	,,	
29-3-10	Standard Mill Tank I Grit Chamber ...	6·0	10·84	2·31	8·53	8·00	1·23	,,	·07	,,	
29-3-10	Standard Mill Tank I Discharge pipe ...	6·0	4·21	1·89	2·32	8·67	·55	,,	·28	,,	
31-3-10	Clive Jute Mill Grit Chamber ..	* 44·4	8·08	3·15	4·93	4·25	1·02	,,	*Nil*	,,	
31-3-10	Clive Jute Mill Discharge pipe ...	44·0	5·61	2·47	3·14	6·15	·66	,,	,,	,,	
8-4-10	Standard Mill Tank I Grit Chamber ...	6·2	10·81	3·15	7·66	7·38	1·15	,,	·07	,,	
8-4-10	Standard Mill Tank I Discharge pipe ..	6·2	4·48	1·69	2·79	7·69	·50	,,	·29	,,	
12-4-10	Clive Jute Mill Grit Chamber ..	* 45·2	8·81	3·33	5·48	5·77	·92	,,	*Nil*	,,	
12-4-10	Clive Jute Mill Discharge pipe ...	45·2	3·74	1·78	1·96	6·31	·65	,,	,,	,,	
Average of Grit Chamber samples		6·0	8·29	2·91	6·32	7·01	1·06	*Nil*	·02	*Nil*	
Average of Discharge pipe samples ...		6·0	4·54	1·96	2·58	7·82	·59	,,	·14	,,	
Percentage of purification on 4 Hours' Oxygen		...	**50·8%**	**Percentage of purification on albumenoid ammonia**			**44·3%**	...	...	...	

	Chlorine.	4 Hours' Oxygen-value.	Saline & free Ammonia.	Albumenoid Ammonia.
Estimated strength of sewage entering these latrines (about 6 gallons per user) ...	6	24	2·0	5·2
Average of discharge pipe	6	4·54	7·82	·59
Total percentage of purification ...	...	81% **of which 61% is accomplished in Grit Chamber and 20% in tank.**	...	88% **of which 80% is accomplished in Grit Chamber and 8% in tank.**

* Due to presence of sea water in the river.

with the mineral residue will therefore remain to be dealt with as sludge."

(2) "The main source of the evolution of gas in the anaerobic decomposition of sewage is from the fermentation of cellulose."

(3) "The amount of organic matter passing away as gaseous nitrogen is very small."

* * * * * *

We have already discussed, at considerable length, the fate of the nitrogen present in sewage when subjected to the action in a septic tank, but analyses of the sludges should be undertaken to see what proportion, if any, of it remain in this material. The following Table VII (*a*) gives the figures taken from the analysis of inlet and outlet sludge in the 3 separate latrines.

TABLE VII (*a*).

TOTAL NITROGEN IN SEPTIC TANK SLUDGES.

	Total N. % of dried sludge.
Standard Jute Mill inlet end ...	3·63%
,, ,, ,, outlet ...	3·27
Shamnagar Jute Mill inlet end ...	2·75
,, ,, ,, outlet ...	2·00
Kanchrapara Shop inlet ...	3·65
,, ,, outlet ...	3·16

These figures are roughly comparable as the amount of mineral matter is not great in the sludges, and it is roughly the same in each sample.

The following points should be noted:—(i) the smaller nitrogen figure present in the outlet samples; (ii) compared with Table IV (*a*) the total nitrogen in the sludges is about the same as in the grit chamber fœces, both having lost 2·5 to 3% of nitrogen.

General conclusions.

Before passing to other subjects, it will be well to recapitulate the main conclusions that have been arrived at in the preceding chapters on the subject of the chemical action that goes on in this particular design of septic tank latrine :—

(1) That in these installations the crude sewage as it leaves the soil pipe contains a very large percentage of hard masses, that are not easily broken up; these masses under ordinary circumstances represent 50 to 75% of the solid organic matter in the sewage itself.

(2) That by making use of the design of the tank with a grit chamber, these fœcal masses remain separated from the main tank for a considerable length of time; while they are present in this compartment, most of the ammoniacal fermentation goes on, so that 50% or more of the total nitrogen is frequently lost, mostly by the diffusion of free ammonia into the water. This action may represent as much as 80 to 90% of the total purification as measured by the 4 hours' oxygen estimation, but in all probability this figure is somewhat above the normal for all latrines.

(3) That the remaining action necessary for a good effluent is completed in the septic tank proper and it is in this compartment, and not in the grit chamber, that the colloidal material is largely disposed of. By the combination of these two actions (that is, of the grit chamber and of the tank proper) a very high degree of purification can be obtained. The analyses in the previous chapter seem to shew that the less action that goes on in the grit chamber, the more goes on in the tank.

(4) That from a very large amount of analytical work on model septic tanks and from a large accumulation of

experience from working installations, a 3 days' rest with a 5-gallon sewage may be looked upon as giving the best result.

(5) That the carbo-hydrate compounds in the sewage are split up in the sludge layer into marsh gas, hydrogen and carbon dioxide. Possibly as much as 50% of the sludge may disappear owing to this gasification of the cellulose residue.

CHAPTER VIII.

AEROBIC FILTERS.

THE next stage in the biological treatment of a sewage is to further purify the septic tank effluent by converting the nitrogenous substances inthe liquid to nitrates; in order to do this an entirely different set of organisms are brought into play, namely, the aerobic bacilli; these are organisms that can only carry on their work in the presence of oxygen. *This is the only really essential part of the whole biological process,* the action in the septic tank being preparatory in nature, and we shall see later that installations have been in common use in which the anaerobic organisms play no part.

The underlying principles in vogue in aerobic arrangements are too well known to require a long discussion. Suffice it to say that any arrangement whatever, which brings the effluent within the reach of certain organisms, that provides ample surface for masses of these organisms to adhere to, and which contain adequate air spaces between the various particles, will nitrify the ammonia in solution, provided the effluent is "dosed" over it in the proper quantity.

The real difficulties of this subject do not lie in the fundamental principles, as is the case in the septic tank, but rather in the working details; such practical points as the best kind of material, the best size to be used, the best way of getting the effluent in contact with the organisms

in proper quantities, and the best way of providing necessary amount of oxygen for the organisms, are the points that require discussion. Of course, there is a wide field of research in the subject of the bacteriology of the nitrifying organisms themselves, but it is not proposed to deal with this aspect of the subject in this work, for, as far as our present knowledge goes, such considerations do not very materially affect the design or method of working of aerobic beds generally.

The subject as a whole divides itself into two parts according to the method of applying the effluent to the beds. These are :—

(1) Percolating Continuous filters ;

(2) Contact beds.

A continuous or streaming filter is a mass of material over which the effluent is continuously sprinkled, the fluid percolates slowly between the particles ; during its passage the chemical changes take place.

A contact bed, on the other hand, is a similar mass of material placed in a tank, the effluent is poured into the material so that it fills up the interspaces, it is allowed to remain for two to four hours, and is then run out of the bed. As the level of the fluid falls, air is drawn into the spaces in the material, thus aerating the mass ; the bed is allowed to rest or recover for a certain period (this is known as the resting stage) at the end of which it can be refilled.

The work of Calmette, Dunbar, Fowler, Letts, Adeny and ourselves in India shows conclusively that, whatever may be the practical advantages and disadvantages of these two methods, good results can be obtained with either, when applied to a suitable sewage. Later on in this work a comparison between results obtained from contact beds and streaming filters will

be given, but the practical good and bad points of these two methods, as applied to the tropical conditions, will claim the largest share of our attention.

Before commencing this discussion a few other matters should be dealt with. The first point that we will take up is, the demonstration of the fact that the domestic sewage of the tropics does not differ materially from that of European countries in the ease with which nitrification goes on. In fact, it may be safely said that the higher temperature is distinctly more favourable for this process than the cold climate of Europe.

A reference should be made to Chapter VI where results obtained from two little model contact beds have been given at considerable length. These are set forth in Table VIII (*a*) and show an extraordinary amount of purification. These little models, which contain, roughly speaking, ·6 of a cubic foot of material, dispose of ·3 gallon of effluent each, the sewage being a 5-gallon one; this is equivalent to three users per cubic yard of material. These figures were obtained with one contact per day of 4 hours' duration, the remaining 20 being available for oxidation and recovery. A subsequent series of experiments were made, giving two contacts of 4 hours each and two rests of 8 hours during the day. These results are given below—Table VIII (*b*).

It will be observed that the percentage purification is very little decreased, whilst the number of users per cube yard of material per day is now 6. The high nitrate figure in the third sample should be noticed, showing that the beds are taking on the extra load and are not overworked. Of course, it must be definitely understood that these are laboratory models; it would not be advisable in a working installation to make use of material that would pass ⅛th of an inch mesh throughout a bed.

TABLE VIII (*a*).

RESULTS OF MODEL CONTACT BEDS ONE FILLING.

Date.	Mixture of effluents from tanks 1, 2, 3 & 4.	Contact bed No. I.					Contact bed No. II.				
				Nitrogen.					Nitrogen.		
	4 Hours' Oxygen value.	4 Hours' Oxygen value.	Chlorine.	Saline and free ammoniacal.	Albumenoid ammoniacal.	Nitrous and Nitric.	4 Hours' Oxygen value.	Chlorine.	Saline and free ammoniacal.	Albumenoid ammoniacal.	Nitrous and Nitric.
15-9-09	3·45	1·95	7·0	1·04	·24	·85	1·33	7·0	·42	·14	1·66
16-9-09	3·11	1·11	6·8	1·28	·18	1·16	·70	6·8	·32	·12	2·65
19-9-09	3·26	1·35	6·6	1·73	·25	·61	·79	6·6	1·11	·17	1·10
21-9-09	3·42	1·14	6·8	·83	·22	1·c6	·69	6·8	·32	·10	3·15
23-9-09	3·67	1·77	7·0	·64	·22	1·33	1·09	7·0	·25	·16	2·20
Average	**3·38**	**1·47**	**6·8**	**1·10**	**·22**	**1·00**	**·92**	**6·8**	**·48**	**·14**	**2·15**
	Percentage purification 86·4. (4 hours O)	**Percentage purification 91·1. (Albumenoid Ammonia.)**					**Percent. purific. 90·5.**	**Percentage purification 94·4. (Albumenoid Ammonia.)**			

TABLE VIII (*b*).

MODEL CONTACT BEDS WORKED WITH TWO FILLINGS PER 24 HOURS.

Date.	Origin.	Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	Nitrogen. Saline and free.	Nitrogen. Albumenoid Ammonia.	Nitrogen. Nitric and Nitrous.	Amount of dissolved Oxygen left dilution 1 in 10. After 24 Hours.	Amount of dissolved Oxygen left dilution 1 in 10. After 48 Hours.	Remarks.
25-4-10	Contact bed 1	8·0	1·25	1·04	·21	1·20	·32	·77	·38	·18	
25-4-10	,, ,, 2	8·2	1·11	1·04	·07	·48	·25	1·37	·59	·57	
26-4-10	,, ,, 1	8·8	1·90	1·64	·26	1·35	·35	·62	·35	·17	
26-4-10	,, ,, 2	8 8	1·31	1·25	·06	·52	·22	1·57	·59	·57	
9-5-10	,, ,, 1	7·2	1·91	1·23	·68	1·72	·44	·49	·52	·18	
9-5-10	,, ,, 2	7·4	·97	·97	*nil*	·75	·18	2·25	·59	·57	
Average	**Contact bed 1**	**8·0**	**1·68**	**1·30**	**·38**	**1·42**	**·37**	**·62**	**·41**	**·18**	
,,	**,, ,, 2**	**8·1**	**1·13**	**1·01**	**·04**	**·58**	**21**	**1·73**	**·59**	**·57**	

Percentage purification C **1 (4 hours 0) 84%. Percentage purification 86%. (Albumenoid Ammonia.)**
,, ,, C **2 ,, 88%. ,, ,, 90%. ,, ,,**

Several other contact beds are working both in models and in working installation in Bengal ; they will be described in a subsequent chapter, but they are not comparable with the results quoted above because, in the latter instances, the sewage has not had a preliminary anaerobic treatment in the tank ; it is perfectly safe to state that, in spite of this difference, the results obtained, support our original conclusions, *viz.*, that contact beds in the tropics will give a good effluent.

Of the ordinary streaming filters there are a fair number in Bengal, the results of which have been carefully collected. Probably the best and most exhaustive examination of the results obtained from continuous filters was carried out when Dr. Fowler was in Bengal, on a filter erected to his own design, attached to the Kanchrapara workshop latrine. His description of the bed and results are quoted from his "Septic Tanks in Bengal."

"The material used was hard furnace clinker, and the grading was as follows from the top downwards:—

6 ins. to pass $\frac{1}{4}$ in. and be rejected by $\frac{1}{16}$ in.
18 ins. to pass 1 in. and be rejected by $\frac{1}{4}$ in.
2 ft. to pass 2 ins. and be rejected by 1 in.
1 ft. to pass 2 ins. and be rejected by 3 ins.
1 ft. large pieces.

"The total depth, it will be seen, was 6 ft.; the upper surface area was 4 square yards.

"The material was placed on a concrete bottom, and the filtered effluent was collected in a channel surrounding the filter and discharging ultimately into the drain carrying the main flow from the latrine.

"The whole material was held in place by an enclosure of wire netting.

"About one-quarter of the flow from the latrine was led continuously on to the centre of the filter by means of a galvanised iron channel and distributed over the surface by smaller radiating channels. A low banking of fine material was arranged to prevent any of the liquid flowing over the sides.

"The filter was brought into work on the 3rd of March 1906, and sampling of the filtered effluent was begun on the 7th.

"In general the samples were taken about 8-15 in the morning (a time of nearly maximum flow in the latrine) and analysed the same day.

"On 7th March a measurement of the flow was made by allowing the flow to run into a 3-gallon bucket and noting the time of the filling.

"The measurement worked out to a rate of 330 gallons per square yard per diem.

"From other measurements it may be safely assumed that the average rate of flow through the filter was certainly 200 gallons per superficial yard, or 100 gallons per cubic yard. This gives nearly 4 gallons per cubic foot, or 1 cubic foot of filtering medium per person." [This statement is not correct, as a careful study of the conditions of working show; the latrine was used more as a urinal, and did not receive its full quota of fœces.]

"Samples of gas were drawn from the centre of the interior of the filter, by driving in an iron pipe, and aspirating into a suitably connected Winchester bottle, by running out the water with which it had been previously filled.

"Analyses of the gas failed to reveal any appreciable quantity of carbon dioxide. The aeration of the filter was therefore concluded to be satisfactory.

" The average composition of the tank effluent and filtrate respectively taking the mean of four complete comparative analyses was as follows :—

	Parts per 100,000. Tank.	Filter.
OXYGEN ABSORPTION—		
Four hours' test (including Nitrites)	2·59	1·16
Three minutes' test	·90	·47
NITROGEN—		
Ammoniacal	5·01	·43
Albumenoid	·195	·055
Nirtous and Nitric	...	2·73
CHLORINE—	5·1	5·0
PERCENTAGE PURIFICATION—		
Four hours' test	55·2	
Three minutes' test	47·7	...
Ammoniacal Nitrogen	91·4	...
Albumenoid Nitrogen	71·7	...

" The samples, with very few exceptions, were clear and bright in appearance, being often indistinguishable from tap water, even when in Winchester quart bottles.

" It is evident, therefore, that a filter of this type, if not overworked, is capable, with but little attention, of giving excellent purification in the case of an effluent from a tank latrine in satisfactory working order."

This will be sufficient to demonstrate that nitrification goes on in a very satisfactory manner, even in concentrated effluents, in both experimental and working installations, in continuous filters and contact beds.

We will now consider the various important points in the design of filters.

Kind of material to be used for filter beds.

The best kind of material for aerobic beds is a substance that is hard, extremely irregular or spongy in structure, so that the amount of surface, in the shape of hollows and crannies, is very much in excess of what would be the case supposing the material was compact in structure. The necessity for the material being hard is obvious, when one considers that filters are usually about 6 ft. deep, consequently the weight of super-imposed material on the lower layers is very considerable; furthermore, the material must be able to resist the action of the sewage itself. If a large proportion of the material forming a bed crumbles, the efficiency is very much reduced and water-logging may very easily occur. As the action of the filter depends on masses of organisms, known as zoogleæ, it is apparent that the more surface each piece of material possesses, the more organisms will attach themselves to it, and, other things being equal, the more purification will be brought about in the sewage.

The best material for making a filter bed is undoubtedly the hard furnace clinker; such a substance has a spongy formation, is very irregular, being entirely made up of irregular hollows. It forms an ideal material from the point of view of giving the maximum surface. Unfortunately, it is extremely difficult to obtain a hard variety in this country, the clinker obtained from Bengal coal being particularly brittle and friable and would "weather" (that is, would crumble) if made into filters.

Iron stone slag forms a fair material for filter beds, but unfortunately there is very little of it available in India; it is used in making a patent flooring material

so that the available supply is entirely made use of. Furthermore, the material contains a considerable amount of lime salts, which set like cement on being dosed with sewage.

Probably the best of the easily obtainable kinds of material for filters is broken "jhama," or over-burnt brick. "Jhama" possesses the advantages of being hard and not likely to "weather," it can be crushed fairly fine, but the fracture being rather clean, the amount of surface is relatively very much smaller than that of clinker. It is, however, very easily obtainable in all parts of India and has given quite good results.

Ordinary road metal, crushed into suitable sizes, may also be used, but there again the disadvantage of the smoothness of the pieces is extremely marked, and consequently it is nothing like so efficient as the material with more surface. An ideal material from the point of view of surface would be the ordinary "kanker" (deposits of lime) which is found in many parts of India. The disadvantages of using this material are, that, it is almost pure Calcium Carbonate; this tends to dissolve in the effluent, precipitating the colloid material, consequently the beds made of "kanker" choke up with deposit and give endless worry.

For the fine material in filters, quartz and laterite, gravel or small mixed pebbles answer fairly well and are fairly easily obtainable in most parts of the country; laterite must be well washed before use, to get rid of the soft material that adheres to the particles, and, as it contains iron salts, it is not as good as quartz. From what we have just said, it will be observed that of the materials available in India none are extremely satisfactory.

The Design of Filter in relation to the grading of Material.

The efficiency of a filter depends on the *total effective surface area of the filtering material*, provided air spaces between the particles are also adequate. This being so, it is obvious, that, the smaller the particles of an irregular material, such as clinker, the greater is the sum of the surface, therefore the greater is the amount of purification. This is broadly speaking true, but it must be remembered that it is the total *effective* surface that is the important factor, and if the material is crushed too fine or too much of this fine material enters into the construction of a bed, the *effective* surface may be very much less in amount than the *total actual* surface. Furthermore, making allowances for the growth of organisms and the deposit of matter from the effluent on the filter material, the air supply will not be satisfactory if too much finely crushed material is massed together; in order to avoid these disadvantages and yet get the maximum efficiency (that is, the maximum effective surface with proper air spaces) filters must be scientifically graded from above downwards. Another very practical consideration must be mentioned, namely, the satisfactory drainage of the filter mass. There must be no holding up of water in the body of the filter; the particles of material must be wetted with effluent, but not submerged in it, air must be present also. In order to allow of free flowing away of the effluent, the lower layers must be of large size.

A reference should be made to the grading of Dr. Fowler's experimental filter. The gradual passing from

the large fragment at the base of the bed to a very fine material on the surface should be very particularly noticed ; in all scientific grading this should be a feature of the construction. The filter in question never showed any sign of clogging, the drainage was ample and an extraordinary amount of purification was obtained. The tank effluent used for this experimental filter contained very little suspended matter and was undoubtedly a good one, the tank itself not receiving its full quantity of fœces; but at the same time the factors which are really responsible for this high purification were (1) the quality of clinker used, and (2) the scientific grading of the mass throughout.

Unfortunately, it is extremely difficult to get the quality of material that was made use of in this filter (the furnace clinker was obtained from the smelting furnace of the railway workshop at Kanchrapara ; there was comparatively little of it), but even with inferior material a very high amount of purification can be brought about *provided the grading is scientific ;* indeed, the greater the inferiority in the quality of the material, the greater care should be exercised in the proper arrangement of the various layers.

In order to demonstrate the importance of carefully laying down of filtering material, reference will be made to several filters, which are inferior in point of design to Dr. Fowler's, the results being proportionately unsatisfactory. The filter of the Lower Hooghly Mill was remodelled at my advice in the following way :—

Two beds, both of $20' \times 20'$, originally intended for contact beds, were converted into percolating filters, the material was ordered to be graded as follows ; in reality there was not much fine material used. Crushed quartz

was made use of, the smoothness of the pieces making a somewhat poor quality material.

	1′ half and whole bricks.
	9″ material pass 2″ mesh rejected 1″.
Practically the whole filter was made of this size	18″ material pass 1″ mesh rejected ½″.
Not put in	18″ ,, ,, ½″ ,, ,, ¼″
	18″ ,, ,, ¼″ and under.

The results obtained from these filters are given below. The two samples, it will be observed, are fairly satisfactory, the effluent being clear and bright in spite of the fact that the grading was not very accurately carried out. There is, however, a large amount of unnitrified saline ammonia present. These results were obtained with about 5 cubic ft. of material per user or about 5 users per cubic yard. This is very different from Dr. Fowler's filter where a better result was obtained with 27 users per cubic yard.

	Unfiltered.	Filtered.
Chlorine	117·0*	113·0*
4 Hours' Oxygen value ...	5·61	1·63
4 Hours' Oxygen value after clarification	2·24	1·43
Colloid Organic	3·37	20
Nitrogen—		
Saline and free ...	2·46	1·17
Albumenoid Ammonia	·31	·57
Nitric and Nitrous ...	*Nil*	1·73
Amount of dissolved oxygen left—dilution 1 in 10		
After 24 hours ...	*Nil*	·47
After 48 hours ...	*Nil*	·35

The above may be looked on as a fair sample as the flow from the tank was about its maximum when this was taken. The following sample was taken when the flow was very low, so that the results obtained are better

* The high chlorine figure is due to the presence of sea water in the river.

than the average. The nitrate figure is satisfactory, though there still remains too much saline ammonia for a final result.

	Lower Hooghly Unfiltered.	Lower Hooghly Filtered.
Chlorine due to sea water in river ...	105·0	89·0*
4 Hours' Oxygen test	5·38	2·00
4 Hours' Oxygen test after clarification	2·90	1·68
Colloid organic matter	2·48	1·22
Nitrogen—		
Saline and free	3·20	1·89
Albumenoid Ammonia ...	·56	·32
Nitric and Nitrous ...	*Nil*	3·88
Dissolved oxygen left—dilution 1 in 10		
After 24 hours	*Nil*	·55
After 48 hours	*Nil*	·17

Some of the Mill Owners in Bengal expressed the opinion, that the fine beds would not be a success on account of the suspended matter in the effluent, which would cause the material to become choked; they have, in consequence, installed filters made up of very coarse material. These filters are mostly ridiculously small and give little or no purification. In order to ascertain the value of a filter designed on these lines, working with a tank effluent similar to what is usually obtained in this country, a small filter was constructed at Shamnagar for experimental purposes; the grading was as follows:—

Drainage layer consisted of whole bricks.

2 ft. "jhama" that would pass 3″ mesh.

2 ft. of "jhama" crushed to about the size of rather large road metal, that is to say, the pieces would pass a 2″ inch mesh but would be rejected by 1″.

4 inches of fine gravel that would pass ½ inch.

* The high chlorine figure is due to the presence of sea water in the riv

It will be observed that the grading is not very scientific and that the particles are large. Another reason for selecting what is apparently an indifferent design was, that it is extremely easy to obtain material of this size, and it is often very difficult and troublesome to get the "jhama" broken into the smaller grades. The material was simply arranged in a heap on a concrete platform, there being no retaining wall, the area of the base was about 6ft. square, the slides sloped up till the surface measured about 3ft. square; the depth was a little under 6ft.; there would be about 4 cubic yards of material in the heap. The filter was started up in November and was allowed to run, in order to ripen, for 2 months with 60 gallons of effluent per hour. The following results were obtained :—

	Tank effluent.	Filter effluent.
Chlorine	4·0	4·0
4 Hours' Oxygen value	4·13	2·29
4 Hours' Oxygen value after clarification... ...	2·29	2·14
Colloid Organic	1·84	·15
Nitrogen—		
Saline and free	6·12	5·77
Albumenoid Ammonia ...	·53	·44
Nitric and Nitrous	*Nil*	*Nil*
Amount of dissolved oxygen left—		
After 24 hours	*Nil*	·40
After 48 hours	*Nil*	*Nil*

It will be observed that although the 4 hours' oxygen figure is considerably reduced, nearly all the colloid material being retained or converted in the filter, the saline ammonia figures remain practically unaltered and no nitrates are present in the effluent. It is obvious therefore that the material is not able to deal with anything like this quantity of effluent per hour. Consequently the supply of effluent to the material was

cut down to 30 gallons per hour. The results are given below :—

	Tank effluent.	Filter effluent.
Chlorine	5·2	4·8
4 Hours' Oxygen test	4·66	2·69
4 Hours' Oxygen test after clarification	2·48	1·46
Colloid Organic	2·18	1·23
Nitrogen—		
Saline and free	6·93	5·20
Albumenoid Ammonia	·41	·30
Nitrous and Nitric	*Nil*	·74
Amount of dissolved oxygen left—		
After 24 hours	*Nil*	·37
After 48 hours	*Nil*	*Nil*

Even with this reduction in the quantity of effluent it will be apparent that the final result is far from satisfactory; there are over 5 parts per 100,000 of saline ammonia and only ·74 of nitrates, the nitrification action being particularly deficient. Thirty gallons per hour per day is about equal to 20 users per cubic yard per day of 16 hours. The amount was further reduced to 15 gallons per hour. The results are given below :—

	Shamnagar Tank 1 unfiltered.	Shamnagar Tank 1 Small filtered.
Chlorine	4·6	4·8
4 Hours' Oxygen test	3·97	1·89
4 Hours' Oxygen test after clarification ...	1·44	·90
Colloid Organic	2·53	·99
Nitrogen—		
Saline and free	5·64	3·78
Albumenoid Ammonia	·55	31
Nitric and Nitrous	*Nil*	1·23
Amount of dissolved oxygen left—		
After 24 hours	·23	·56
After 48 hours	·03	·28

This shows considerable improvement, but the tank effluent has improved considerably in quality in the last

week. This result is obtained with about 8—10 users per cubic yard, and is about the best that could be expected from a bed designed as above.

Other examples of unscientific grading and consequent bad results could be cited, but these will be sufficient.

Dr. Fowler has laid down that 20 persons per cubic yard per diem can be allowed with filters properly graded like his; we are inclined to consider that this allowance is too high. His filter gave the results previously quoted with 27 users per cubic yard, but the effluent which was used was admittedly a good one and was obtained from a weak sewage. Further, in small experimental filters, proper distribution is easy, consequently abnormally good results are likely to be obtained from these models. In working installation, in which the effluent is a good one, and in which the filtering material is fine and properly graded, we consider that 15 users per cubic yard of material per diem is a safe number. This leaves a margin for accidental variation in the quality of the tank effluent.

If, on the other hand, the particles of the filtering material are, for any reason, larger and the grading less carefully arranged, the number of users per cubic yard should be very much reduced. Thus if the smallest pieces used in any filter would pass 1″ mesh and be rejected by ½″, but the mass of the material was larger than this, 10 users per cubic yard would be as much as the bed would take; if the smallest pieces were to pass 2″ and be rejected by 1″, 3–5 users would be sufficient. Of course, in all these estimates it is presumed that a very pure and fully nitrified effluent is desirable, the results obtained by Dr. Fowler's filter being taken as the standard, but this may be unnecessarily high; in all cases the quality of the effluent desired must be fixed for each installation

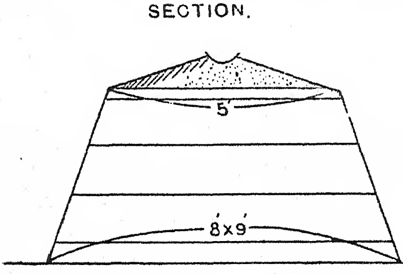
according to circumstances, particularly bearing in mind how the effluent is to be disposed of. Thus it would obviously be waste of money to set up large filter beds and fully nitrify an effluent, if it were passed over land, whereas if it was to be discharged into a small stream, a high degree of purity would be desirable.

THE DESIGN OF FILTERS IN RELATION TO THE DISTRIBUTION OF THE EFFLUENT.

The cheapest and most efficient variety of percolating filter is in reality nothing more or less than a heap of properly graded material, standing on a masonry platform sloped in such a way that the effluent will flow towards the drain. There is no real necessity for enclosing the material with a wall, pigeon-holed or solid. The heap may be built up the same way as coal is stacked in engine yards and similar places. It is advisable to have large pieces round the outside of the heap, because by this means the slope at which the finer graded material will stand is considerably increased, and these large masses protect the inner layers from the sun and hot winds.

The shape and general arrangement of the filters must be decided according to the method of distribution to be used. It will be noticed in the grading of the filters, previously described, that in every instance a layer of very fine material is placed on the surface. The object of this layer is to facilitate the distribution of the effluent. The finer the grading of the top layer, the more the effluent tends to spread out, and by the time the fluid reaches the larger material it is evenly distributed throughout the mass. This arrangement is called by Dr. Fowler a "controlled" filter; the advantages of it are, that, with this device, a very simple sprinkling or "dosing" mechanism can be utilised.

Now in the design of filters two factors must be taken into account: (1) that the larger the filter bed the more difficult it is to distribute the effluent over it, without having recourse to mechanical apparatus; (2) the larger the pieces of the material used in the construction of filters, the more accurately must the distribution be. Hence it is obvious that before deciding on the shape of filters, the first thing to decide is, how is the effluent to be sprinkled over the surface?



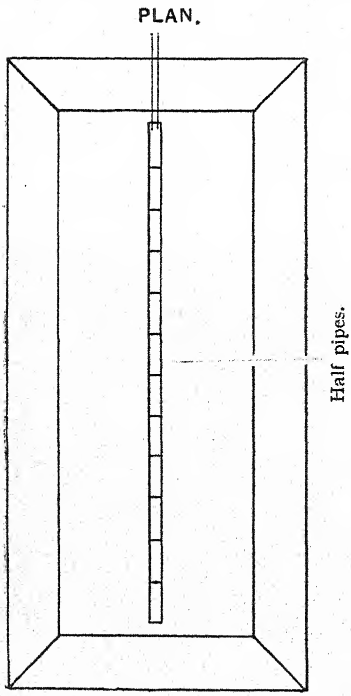


FIG. VIII (*a*).

In Bengal, where the available fall is extremely small, and where the mechanical sprinklers are distinctly objectionable, the ordinary method of sprinkling is to make use of a controlled filter with the simplest possible form of distributor. A very satisfactory method of arranging filters is shewn in figure No. VIII (*a*).

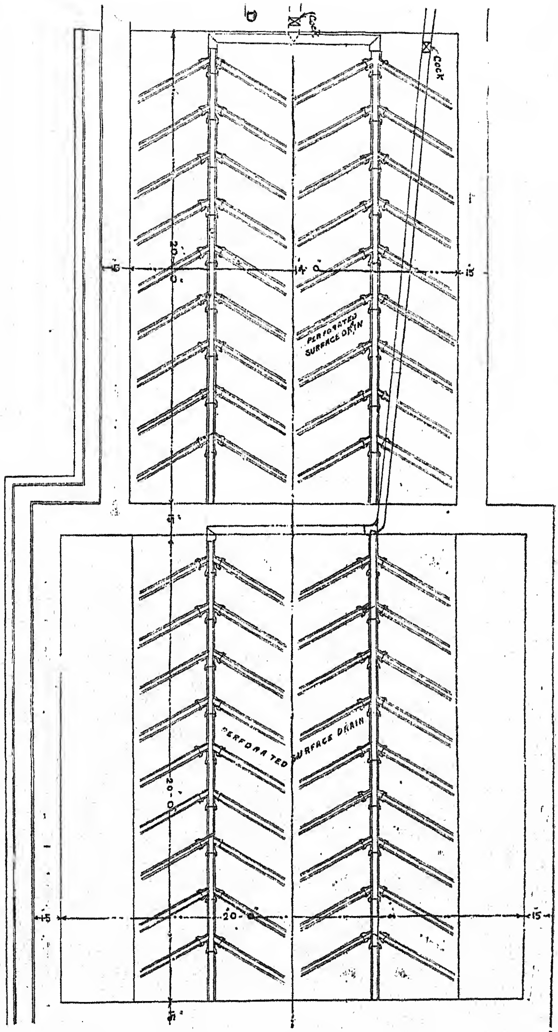


Fig. VIII (c).—Distribution arrangement of Lower Hooghly Mill.

In this case the filtering material is carefully graded, the top layer is fine, the beds are arranged side by side, they are long and thin in shape and the distribution is effected by a single line of unglazed pipe along the summit. Another very satisfactory way of distributing the effluent is shewn in fig. VIII (*b*) in which a sort of herring-bone distributor is made of half pipes, the joints being open. These filters give extremely good results when properly constructed, the pipes require a little careful adjustment, so as to get the effluent to run evenly over the surface of the beds, but when once fixed up, give little or no trouble and are both cheap and efficient. This kind of bed is, however, slightly wasteful of material and takes up rather a lot of space; but the advantages of cheapness, efficiency, etc., preponderate over these objections. Fig. VIII (*c*) gives a plan of the distribution arrangement of the Lower Hooghly Mill, the results of which have already been quoted. The beds are square, because the tanks in which they were constructed were orginally intended for contact beds. It

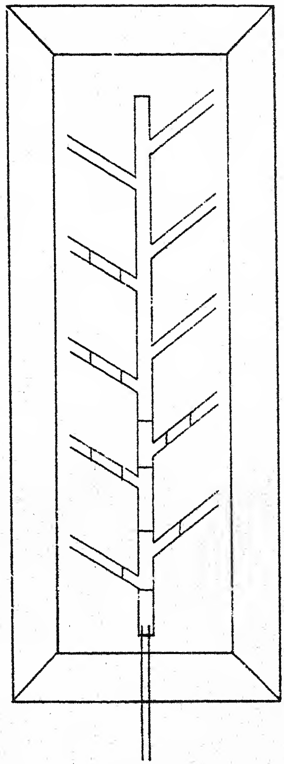


FIG. VIII (*b*).

would have been distinctly better to have arranged the filtering material in longer and narrower heaps, but even with square beds these half pipes give a very fairly satisfactory distribution. It is not advisable to have filters too long or too large, 15 to 20 ft. is sufficient in length, the width to be arranged to accommodate either a single or double pipe running down the surface.

It is perfectly safe to say, that, with a suitable shape of bed, with a properly graded material, and with a little care in laying these pipes, no more complicate arrangement is necessary in order to obtain a very satisfactory result. Of course with accurately working mechanical sprinkler the same results might be obtained with perhaps 20% less material and possibly 33% less ground space ; but for the small installations common in this country, this is not a great matter, as we shall see later, the disadvantages of mechanical sprinklers are so very great, that we recommend whenever possible to make use of this simple and cheap arrangement. We will now pass on the subject of sprinklers.

Sprinklers can be roughly divided into two kinds, the jet (or modification of the jet sprinkler), and the mechanical sprinkler. The jet sprinklers are on the whole extremely satisfactory, specially the modification given in figure VIII (*d*). The disadvantage of this type of jet sprinklers is that it requires a certain head of water to make it work properly; when this head is available, very good results are obtained. The modification of jet sprinkler, which was made by a Mill Manager close to Calcutta, possesses some advantages over the usual type. In the first place, it requires less head to work it because the pipes can be sloped in such a way as to create a satisfactory fall ; furthermore if sediment tends

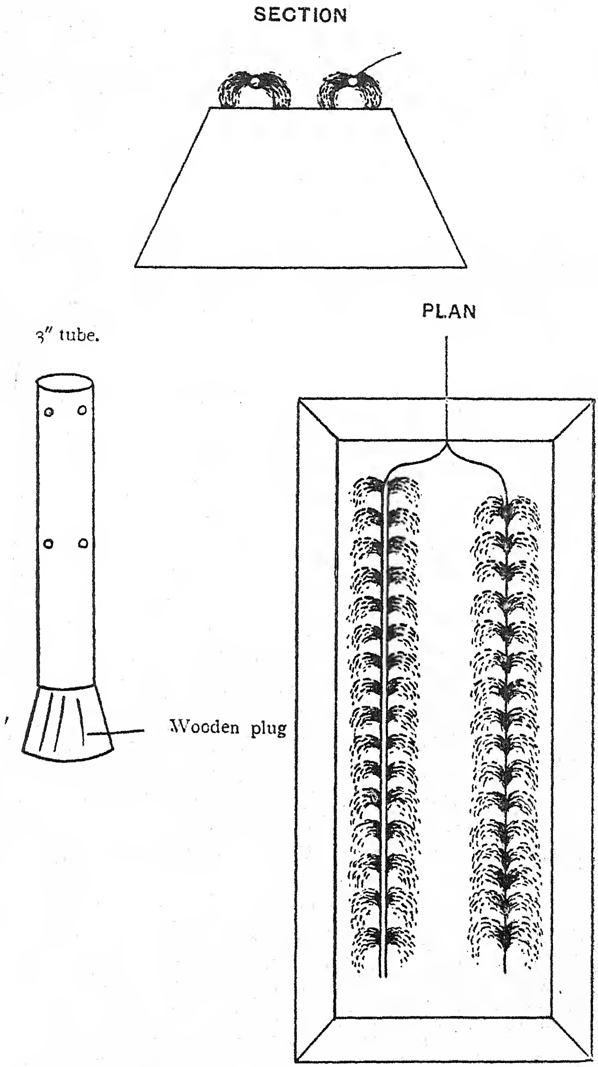


FIG. VIII (*d*).—Jet Sprinkler made by drilling holes in a large pipe.

to collect in the pipe it can be easily removed by removing the plug at the end of the pipe. This type of jet sprinkler can be very strongly recommended as being both cheap, giving satisfactory results, requiring very little attention. The ordinary jet sprinkler is extremely useful in hill stations where considerable head is available.

Dr. Fowler has laid down the following conditions that all distributors should fulfil :—

(1) "It must not be too expensive, either in first cost or up-keep, for the work it has to do (the daily cost of some of power-driven sprinklers is considerable).

(2) "It must be simple in construction and not easily put out of order.

(3) "Its movement must not be easily interfered with by growth or suspended matter from the tank effluent.

(4) "It must not be readily interfered with by climatic conditions, *e.g.*, wind or alteration of temperature.

(5) "It must not, if relying upon the incoming effluent for motive power, require a greater rate of flow to be maintained than the filter is capable of efficiently purifying.

(6) "It must distribute the effluent equally over every part of the surface of the filter."

To these conditions may be added that brass should not form any part of the structure of the sprinkler, for it is pretty certain to be stolen by the mill coolies. It is extremely difficult to find any kind of sprinkler which really does fulfil all the above conditions, and supposing that engineers have designed such a wonder, for small installations, the only advantage that can be claimed for it is, that it is possible to somewhat reduce the space occupied by the filters, and somewhat reduce the quantity of material required. These advantages only become

of moment when dealing with large volumes of sewage in crowded localities, such as town disposal works in Europe. The disadvantages are many and important: (1) it is of the utmost importance not to have anything in connection with the sewage installation which may possibly get out of order, or which may require the attention of anybody but a sweeper; (2) a large number of the mechanical sprinklers render it necessary to enclose the filter bed with a wall, either pigeon-holed or solid; this increases the cost of construction of the filters; (3) sprinklers are distinctly costly things, and practically all varieties have some serious fault, which renders them unsuitable for this country.

From considerable experience of what can be done by the use of "controlled" filters, we are forced to the conclusions that mechanical sprinklers play a purely ornamental part in the small installations in tropical countries; extraordinarily good results have been obtained without them, by the use of little care in the selection of size, shape and the number of filters, consequently why go to the expense? And why instal an apparatus which is sure to get out of order sooner or later, and which no skilled mistry will touch?

Before leaving this subject something must be said about the automatic "dosing" apparatus. These in our opinion are more satisfactory than the mechanical sprinklers because their action is much more positive, and the best of them are certainly less liable to get out of order. Unfortunately, however, they are rather costly, and the often-recurring objection, namely, that no native mechanic will touch them, because they are used in a sewage installation, still applies.

The result of our experience in this country with the filter may be summed up in a sentence; that the proper

grading of the filtering material is the vital point in the construction of a filter, if this is properly attended to, particularly if the filter is controlled by a fine layer on the surface, very simple distributing arrangement give very satisfactory results.

THE WORKING OF THE CONTINUOUS FILTERS.

Continuous filters, when properly designed and when once properly started, require little or no attention, the flow of effluent goes on satisfactorily night and day, there are no valves to open and shut. It is not unusual to find that certain mill-owners having two or more filters use them on alternate days. This arrangement is not satisfactory, for if the two filters together are just sufficient to nitrify the effluent in 24 hours, it means that each filter is overworked, or if one bed is sufficient for the work in 24 hours, then there is no necessity to go to the expense of having two.

When the tanks are new, they invariably give out more suspended matter than older tanks. Furthermore, when the tanks are filling up with sludge, the effluent contains more solid matter than when they are clean (because the gas generated stirs up the sludge), consequently it is advisable in new filters to have a large reserve of fine material, as frequent scraping may be necessary until the tank has had time to ripen ; it may be better to remove the upper 18 inches of filtering material altogether, wash it up and replace it and then add the controlling fine layer on the surface.

From time to time it may be necessary to rake over or even to scrape the surface of the filter, but this is a comparatively simple procedure and should not be required oftener than once in a fortnight or once in

a month, if the tank is giving a good effluent. Some of the mill-owners in the neighbourhood of Calcutta object to use this fine material, believing that it will rapidly block up, due to the suspended matter that is brought over with the effluent; when such objections have been raised, it is invariably found, that the latrine complained of is seriously overworked and is pouring forth enormous quantity of such material as tomato-skin, potato-skin and husks of rice and dal, which of course choke the layers of the filter. The remedy for this state of affairs is not to over-work the tank; but in some old installations of faulty tank design, the simple straining arrangement given in the figure VIII (*e*) may be interpolated between the tanks and the filters. In this way all suspended matter can easily be removed and the choking of the top layers of the filter beds prevented. It should be clearly understood that the apparatus shown in the figure is not, or should not be, an essential in a properly designed septic tank installation, for we have many installations where no such arrangement exists, and which never suffer from blocking up of the material. This simple remedy may be borne in mind to correct faulty tank construction.

Advantages of continuous filters.

From what has been said before it is obvious that continuous filters possess the following advantages:—

First of all, they are cheap; the only construction that is required (and that is not absolutely necessary) is a masonry floor; no retaining walls are necessary.

Secondly, when properly designed, they contain absolutely nothing that can get out of order.

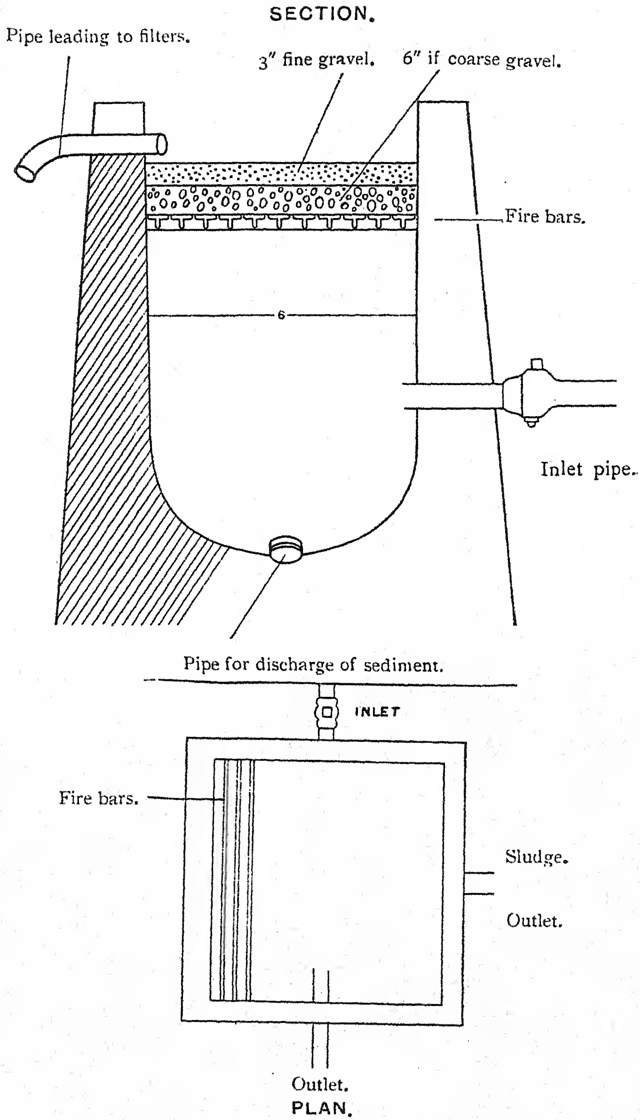

SECTION.
Pipe leading to filters.
3″ fine gravel.
6″ if coarse gravel.
Fire bars.
6
Inlet pipe.
Pipe for discharge of sediment.
INLET
Fire bars.
Sludge.
Outlet.
Outlet.
PLAN.

FIG. VIII (*e*).

Thirdly, they are very largely to automatic. There is no necessity to open and shut the valves at stated intervals, a matter which, though apparently trifling, is never done satisfactorily in the East.

Fourthly, they are sanitary and do not give rise to nuisance or form breeding grounds for flies.

CHAPTER IX.

THE DESIGN AND ARRANGEMENT OF CONTACT BEDS.

FOR reasons that will be explained later contact beds have not been utilised to anything like the same extent as continuous filters in Bengal; consequently, although careful study has been made of those that do exist, our knowledge is not based on quite so much experience as is the case with other aerobic arrangements.

The definition of contact beds has already been given in the preceding chapters; the main difference between this arrangement and continuous filters is, that, the effluent to be nitrified, instead of being sprinkled over the material in a steady stream, is allowed to fill up the interspaces in the mass, to remain in this position for a fixed period of time and finally to flow away. During the period of contact, the aerobic organisms are busy in absorbing from the fluid the nitrogenous material upon which they exist. In three or four hours the effluent is run off, air re-places the fluid in the spaces and the absorbed ammoniacal substances are converted into nitrates, which are given out with the next dose of effluent. One point is perfectly apparent, namely, that if the effluent is allowed to remain too long in the contact beds, the aerobic organisms, being deprived of oxygen for too long a time, will tend to die and the activity of the beds will be spoilt.

In successful contact beds there must always be *a ratio between the amount of nitrogenous material per gallon of sewage, the length of time that it is left in contact with the organisms and the length of the resting period.* A study of the strength of the sewage, and a little experimenting with the contact bed to be used, will give the best arrangement of these various factors; thus, in a very dilute sewage (say 50-gallon sewage) an hour and-a-half or two hours' contact with the material, and three hours' rest for aeration of the bed may give the maximum purification desired; in this case no less than 4 fillings of the bed in the 24 hours would be possible. For a concentrated effluent, such as we have in this country, with its enormous quantity of free ammonia and other nitrogenous material, a 4-hours contact and 20-hours rest for aeration and digestion of the absorbed nitrogenous material may be necessary; in this case only one filling per 24 hours would be possible. The period of contact cannot be extended much above 4 hours, however strong the sewage, for fear of drowning the organisms by depriving them of oxygen for too long a period.

The subject of the best dilution for contact beds, the quantity of material per user, and the chemistry of the changes generally, will be discussed at length in the succeeding chapters, but the following directions for working contact beds may be accepted as correct. For effluents derived from the usual septic tank, fed with a 5-gallon sewage, whose chemical constitution is the same as those already described, contact beds should always be designed to give at least 2 fillings in the 24 hours, the best timing being 4 hours' contact and 8 hours for aeration or rest. Unless it be possible to give two fillings to the beds in 24 hours, contact beds are not

economical, the number of cubic yards of materia necessary, and the amount of ground space required, making the installation so large as not to be able to compete with the continuous filters. Having laid down the above condition, we will now discuss the various points in the design of the beds.

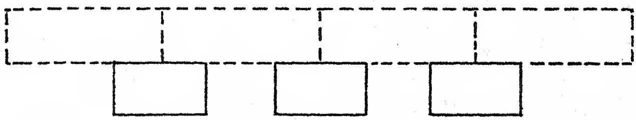
The Best Material for Contact Beds.—What has already been said on the subject of material for continuous filters applies absolutely to contact beds, the ideal material being hard furnace clinker ; this unfortunately is not obtainable in India ; " Jhama," road metal, quartz, gravel, etc., have to be used as a substitute.

The Grading of the Material.—In a contact bed we do not attempt to dose each part of the material with an exact quantity of effluent. We simply fill up the interspaces with fluid and allow them to remain full for a fixed period. Consequently the grading of the contact bed is nothing like of the same importance as it is of a continuous filter, but it is very necessary to provide adequate drainage of the whole mass. The material for contact beds should be fine, for the reasons already given, namely, that the finer the material, the more the surface, and the greater the purification. Of course, it must be stated that the finer the material, the easier the bed chokes up, the more often it will require removing and washing up. For this country we recommend that the bulk of the bed be constructed of a material that will pass $\frac{1}{2}$ an inch mesh and be rejected by $\frac{1}{8}$th ; all dust and finer particles should be washed away. The material must, of course, be hard and not liable to crumble.

The drainage of a bed of this kind requires very great care. We have seen several instances where the drainage arrangements have been deficient and the beds have not given good results, simply because they could not be

emptied rapidly. It is a rule in the construction of the beds, which should never on any consideration be departed from, *that a contact bed should never take longer than half an hour to fill, or half an hour to empty*, if it takes longer than this, it is perfectly impossible to arrange the period of contact and rest properly; of course, this does not mean that the bed will not go on draining slowly during the whole of its resting period, but 90% of the total fluid capacity of the bed should be removed in half an hour. From a number of experiments, carried out on the Gouripur installation, the following arrangement of drainage has proved to be the best :—

A double layer of bricks set in the same way as for sand filters, arrangement as shown in fig. IX (*a*). It is



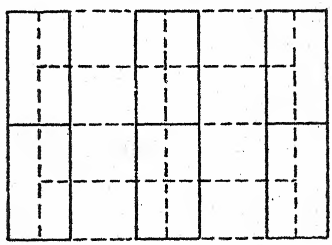


Fig. IX (*a*).

sometimes desirable to have tongues of coarser material, about a foot square, in the mass of finer material. We

have found that ordinary drain pipes without the bricks have not answered well; unless a very large number be used, they do not remove the effluent sufficiently rapidly from the bed; they tend to choke up and waterlog the lower layers.

Material finer than $\frac{1}{2}''$—$\frac{1}{8}''$, that is to say, a material that will pass $\frac{1}{4}$ inch mesh, but be rejected by $\frac{1}{16}$th, may be used for contact beds, provided the drainage arrangements are constructed on the lines given above. Material of this size, however, is both difficult to obtain and to manufacture without power-driven crushers. On the whole, we consider the maximum economic efficiency is to be obtained from a slightly coarser material, namely, that already mentioned, particles varying from $\frac{1}{2}$ to $\frac{1}{8}$ inch in size. Further, if the material is too fine, the fluid capacity of the bed is small and is easily reduced.

Contact beds may be any depth, 3—4 feet is probably the best, but a bed 18 inches deep of very fine material, when properly drained, would give a good result and may be indicated in some places where fall is deficient. Beds that are deeper than 5 feet do not aerate so well.

Contact beds may be of any shape according to the circumstances and conditions of each installation. In Manchester they are squares, but rectangular beds of any size answer perfectly well. It is very important to have adequate filling and discharging arrangements. It is recommended never to use valves less than 4 inches in diameter unless the beds are very small, for it is of vital importance to be able to fill up and discharge rapidly. The fluid capacity of a bed filled with material of the size described above will be, when new, about 33% of the total capacity. Unfortunately this capacity tends to decline and after some years' work will drop to

25%, to 20% or possibly lower. This indicates that the material of the bed requires removing, washing up and replacing. With thoroughly satisfactory drainage, with careful looking after, and with a good effluent, this process of renovating the bed should not be necessary in less than 5 years; but careless working of the beds and deficient drainage arrangements may render this operation imperative in as short a time as 2 to 3 years. Under any circumstances when it is decided to make use of contact beds, the fact that washing up of the material will eventually be necessary, must be carefully borne in mind. If the installation is a large one, the cost of this operation is considerable, and financial arrangement must be made accordingly. When Dr. Fowler was in charge of the Manchester works, he considered that his contact beds would require washing up every 5 years, and, that removal, washing and replacement of crumbled material would cost 18*d*. per cubic yard. Of course, in a small installation, to which class the great majority of those required in India belong, the cost is much less important than the difficulty in getting men to carry out the work, or the annoyance occasioned by having an installation thrown out of work.

On the surface of the material shallow drains as shown in the picture, fig. IX (*b*) & (*c*), should be cut sloped from the inlet so as to facilitate the filling of the bed. These not only carry the effluent over the mass, but by this simple arrangement much suspended matter is retained in the bottom of the shallow channels and is very easily collected and removed. It is also advisable in some cases to fill up the bottom of these drains with a fine material, such as a very coarse sand, or fine gravel, and to keep replacing this, as scraping of these channels

is necessary. By this simple means a very large amount of material, which would otherwise find its way

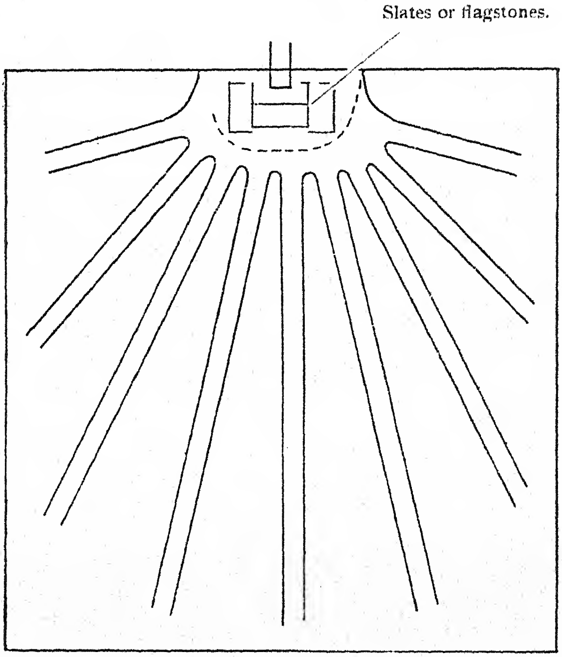


Fig. IX (*b*).

into the mass of "clinker," is retained on the surface and can be removed.

Of course, as the beds stand full of fluid for a considerable number of hours, masonry tanks have in all cases to be constructed. The use of ferro-concrete has reduced the cost of construction of these considerably, but it is obvious that the amount of masonry required for a satisfactory installation of contact beds is very considerable.

Where contact beds are to be made use of, it is always necessary, in this country, to provide an im-

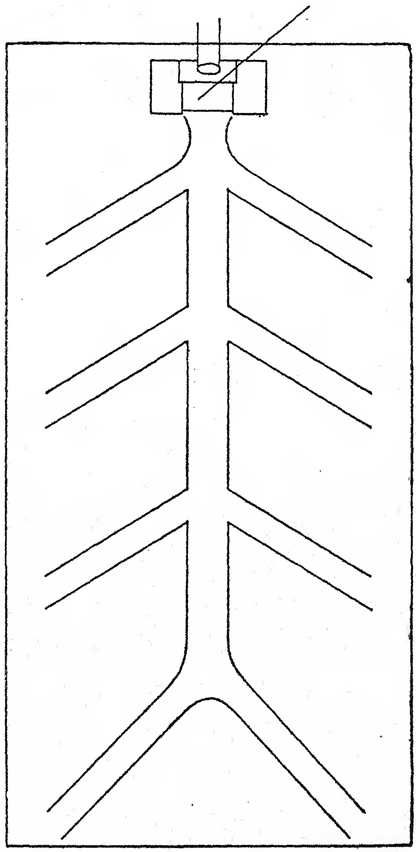


FIG. IX (*c*).

pounding reservoir for the effluent; if this is not done, it is impossible to keep the timing of the beds accurate

and it is also impossible to fill up the beds rapidly. The rate of discharge from a septic tank may be only five or six hundred gallons per hour. If a contact bed has a fluid capacity of two thousand gallons, it follows that at this rate of flow it will take 4 hours to fill. It would be impossible to work a contact bed that fills so slowly as this, for it would be impossible to decide from what moment the period of contact commenced, and it would mean that the lower layers of the bed would be submerged for perhaps 6, 7, or 8 hours; this would destroy the action of the lower layers and would cause them to choke, thus interfering with drainage. Hence an impounding tank from which beds can be rapidly filled is a necessary part of the installation.

Advantages and Disadvantages of Contact Beds.

The advantages of contact beds are somewhat few and far between. They have, however, one decidedly good point, which is as follows :—

A very satisfactory purification can be obtained by using large and shallow contact beds, in places where the available fall is small; thus, if the fall available was only 3 feet, a system of carefully constructed, fine contact beds would give a thoroughly nitrified and good effluent, whereas it would be almost impossible, with only 3 feet fall, to get a satisfactory purification with continuous filters. A contact bed 18 inches deep will give excellent results. A double contact, in two shallow beds of this depth, could be made to give an effluent quite as satisfactory as that obtained by the very best streaming filters six feet in depth. Of course, the

cost of construction of these shallow beds would be very great, but it might be justifiable under certain circumstances.

(2) Another advantage of contact beds is, that they are better adapted, due to the arrangement of periods of contact and periods of rest, to the class of installations which depend on aerobic organisms throughout. This method of disposal of sewage will be discussed fully in the next chapters, and the point will be better understood after a description of these installations has been given.

The disadvantages of contact beds are numerous. First of all, by far the most serious objection to the use of contact beds in the tropics, is the fact, that they require careful working and regular opening and shutting of certain valves. It is true that some firms have designed arrangements which automatically open and close (such as Adams' mechanism), but these cannot be recommended for use in India. Electrical apparatus has not yet been perfected sufficiently to make it possible to open and shut contact bed valves by this means.

In India it is extraordinarily difficult to get any individual, who is either sufficiently intelligent or sufficiently reliable, to be entrusted with the opening and shutting of the valves in a contact bed installation. The "sweeper" of this country cannot be made to understand the absolute necessity of working the beds regularly; a particularly cold night, or a heavy downpour of rain, is quite sufficient excuse for not carrying out his duties properly. What can you expect from the class of man, who refuses to do night work, because he reports that he found a devil sitting on the valve handle? One does not wish to malign the native

sweepers of this country, who undoubtedly have many very good qualities, but accuracy and punctuality in carrying out their work are not amongst these; consequently contact beds should never be installed in places where European supervision is not available. From a very considerable amount of experience we are able to state that it is practically impossible to get a set of 4 or 6 contact beds worked properly by the ordinary agency available.

Contact beds are much more costly both in initial cost, in working expenses and in upkeep charges, than continuous filters. An impounding reservoir is necessary for the effluent. Masonry tanks to contain the material (even though they may be made in the most economical way) cost a considerable sum; the number of large valves is also a considerable item. In streaming filters all that is required is a small masonry platform and a heap of material.

Contact beds vary in their fluid capacity, and require periodic washing up. With a small installation such as we have in this country, this may not be a very great matter as regards expense, but it is a serious matter in a large installation.

The chemical efficiency per cubic yard of material as compared with streaming filters will be discussed in the next chapters.

From the above it is obvious, that, at any rate in a small installation in India, a satisfactory design of streaming filter is the best under ordinary circumstances; it is both cheaper, more efficient, requires less attention than contact beds. In fact, contact beds possess so few real advantages and so many serious objections that they cannot be recommended in India except under very particular circumstances.

CHAPTER X.

MISCELLANEOUS MATTERS CONNECTED WITH THE SEPTIC TANK LATRINE.

IN the preceding chapters we have discussed the design of the latrine, and the chemistry of the process that goes on in the tank. There are, however, a few very important minor matters which require comment.

LATRINE ACCOMMODATION NECESSARY FOR A GIVEN POPULATION.

Since the installation of self-recording turnstiles some very interesting figures have been recorded by some of the mills. These enable us to state, with a reasonable amount of certainty, what proportion of the population of the jute mills visit the latrines in a working day. The figures given by the Standard, Auckland, Reliance and other mills are of great interest and importance; they all agree to a remarkable extent. It is not necessary to give all the details; the conclusions arrived at are as follows:—

In the ordinary jute mill, working from 5 in the morning till 8 in the evening, the labour working in 3 shifts, *about* 86% *of the total population use the latrines where separate urinals are provided;* but if urinating in drains of the mills is prevented, and, if the users

of the urinals are counted by the turnstile, and are included in the daily total, it is usual to find that about 10% or 15% more than the total population of the mill visit the latrine; that is to say, that some persons pay more visits than one in the working day.

The great exceptions to this rule are the Government Factories, Railway workshops, where the labour is of much superior quality, and where the hours of working are from 8 A.M. to 5 P.M. with an interval at noon, there being no shift of workers in the shops. From some very carefully kept figures in the Rifle Factory, it is found that only about 25% to 33% of the total population use the latrine. The difference is very striking and is due to the fact that the cooly labour of the jute mills, commencing at 5 A.M., attend the call of nature during the working hours, whereas the *mistries*, who only commence at 8 A.M., have usually done this before arriving at their work. Similar figures were collected, at my recommendation, in Jamalpur Railway Workshops, where some 10,000 labourers are employed from 8 A.M. to 5 P.M.; it was found that a little less than 33% use the latrines, separate urinals being provided.

Of course the results obtained from jute mills and railway shops, may be taken as correct for such institutions, but it is not maintained that the estimate of the population using the latrines is the same in all parts of India or in other types of workshops. Therefore, when considering the advisability of putting in a septic tank latrine, one of the first points to be ascertained is, what proportion of the labour under ordinary circumstances visit the latrine during the day. Having ascertained this figure, a certain amount of margin, say 10 to 15%, should be allowed above this, for there is no doubt that septic tank latrines are distinctly popular

amongst the cooly class, and deferring of the morning visit till working hours is sometimes observed.

The number of seats to be provided for any mill should be about one seat to every 50 workers; thus in an ordinary jute mill, with a population of 2,000 hands, 100% of whom will probably use the latrine, at least 40 seats should be provided. This does not seem a very liberal allowance, but it should be remembered that there is never more than two shifts, that is, two-thirds the total population of the mill, working at one time. If on the other hand, the institution is a workshop, where only about 600 out of the total 2,000 people will use the latrine, 15 to 20 seats will be sufficient.

Points to be considered in deciding whether to instal a septic tank latrine.

From what has already been said, it is obvious that two or three fundamental questions require satisfactory answering, before it is possible to decide, whether a septic tank latrine is suitable to the conditions of any given place or community. These questions are—

(1) Is the water-supply adequate for the present needs of the population and for the latrine?

(2) Is there a sanitary and easy method of getting rid of the effluent?

(1) Water-supply.

Sufficient has already been said on the absolute necessity of having a really adequate supply of water for a septic tank latrine. If there is any real doubt as to whether the supply of a town will be able to meet the demand, this point should be finally settled before this

matter is allowed to proceed further. Septic tank latrines, as designed by us, do not theoretically require a very large supply of water; thus a latrine for 2,000 people should require 10,000 gallons of water ; as a matter of fact, nothing less than 15,000 gallons should actually be available. Our experience, obtained by gauging the quantity of effluent passing through a latrine in this country, shows, that the consumption of water is more than was expected. This, in most cases, is due to defective flushing apparatus, which wastes water. With properly designed automatic apparatus this error can be largely eliminated.

In towns without a filtered supply the water may be obtained from a neighbouring tank, but this always means a very considerable increase in the initial and working cost of a latrine .The cost to the latrine may be somewhat reduced by making the pump serve the double purpose of supplying flushing water for drains, water for watering roads, etc., and in this way debiting some of the cost to other municipal departments. When special pumping arrangements have to be made, the advisability of building 4 or 5 septic tank latrines for a part of a town should always be considered, so as to put in an adequate pumping plant, and to reduce the cost per latrine. Where the water is not taken from an ordinary town service, specially large storage, on the latrine itself, should be provided, so as to avoid all chances of the supply failing and to allow of reduction in the number of hours of pumping as much as possible

(2) Final disposal of the effluent.

It is not proposed at this point to discuss the relative advantages of the various methods of disposing of

the effluent; all that we are interested in at present is, to ascertain whether one of the many ways is possible and whether it is free from objection. Thus the chief points necessary to decide are: (1) Is there sufficient fall to carry the effluent away? (2) What sort of channel will have to be made for this purpose, and how much it is going to cost? and (3) Is there any objection, on the ground of nuisance or the likelihood of disseminating diseases in the method of disposal selected?

The usual methods of disposing of the effluent is to run it over land, or into rivers, tanks or marshes. But it must always be remembered, that effluent in itself is a dangerous fluid; the best contain a very large number of fœcal organisms, and the possibility of contaminating a drinking water-supply should always be kept in mind.

Of course 10,000 gallons of effluent per diem is a very small quantity and can usually, with a little ingenuity, be disposed of in some way or other without any danger to the public health, but the chief point to be emphasised is, that, the method of disposal should be investigated and decided on *before and not after* the latrine is constructed. Of course, it very materially adds to the engineering difficulties if there is no fall available in the locality, but this can be overcome by raising the latrine.

There still remains one point, and that is, the advisability or otherwise of allowing the effluent to flow down open drains. From a very considerable amount of experience it is perfectly safe to say, that there is no objection on sanitary grounds, as long as the effluent is non-putrescible, but it is occasionally not very desirable for other reasons. If the drain into which it is proposed to discharge the effluent happens to be an ordinary road-

side drain, containing a lot of sullage and other material, which renders the contents unpleasant looking and dirty, there is no particular darger ; but if the effluent is bright and clear and the drain clean, there is a possibility of the drain contents being put to undesirable uses. It must be remembered that the natives of India judge of the quality of water merely by its appearance ; we have seen people in a bazar washing their clothes and cooking utensils in a large open drain, which contained a very fair proportion of septic tank effluent, simply because the contents were clear, and, to the eye, looked perfectly pure ; consequently one must be guided by local conditions in every instance. There would be no harm whatever in running septic tank effluent down some open drains, but it would not be sound to run a large quantity of clear, bright septic tank effluent down an open drain in a dry and arid place, for in some parts of the country it would invariably result in the effluent being used for washing purposes and probably being drunk by the children. In surroundings such as these it would be better to carry the effluent away in an underground sewer.

Particular uses of septic tanks.

In our introductory chapter we made a somewhat bold statement, namely, that we believe we were now able to substitute something more sanitary in place of the ordinary hand-removal latrine, with its evil-smelling attendant carts. Up to a certain point there is no doubt that this statement is correct ; we will now discuss how far this substitution is possible. The advantages of a well-designed septic tank latrine over the usual hand-removal latrine are, we take it, fairly

obvious. A properly designed septic tank latrine is a thoroughly sanitary arrangement, and is to be recommended whenever the conditions are favourable. It is in the long run economical, for it does away with a large number of sweepers, carts, bullocks, and trenching staff, that are necessary for a hand-removal latrine.

From what has already been said it is obvious that a septic tank latrine is pre-eminently satisfactory when it is applied to a separate community, such as the labour of a mill or workshops, the inmates of a school, lunatic asylum, jail or similar institution. It is in connection with places such as these that septic tank latrines came into existence in India, and in surroundings of this kind, everything is favourable for their installation. Large workshops must have plenty of water, and plenty of available power. As workshops and mills are frequently situated on the banks of large rivers, there is little or no difficulty with the disposal of the effluent. European supervision is available on the spot, and persons possessing highly trained engineering skill are also within easy call. Furthermore, one condition, which favours a good result in a septic tank latrine, is the regularity with which it is used by a known number of persons per diem. At one time in the course of our experience probably undue stress was laid upon this point, but since we have discovered the enormous amount of purification which goes on in the grit chamber, it is possible, by slightly altering the design, to make a latrine much less susceptible to these variations in the number of users. Hence it is perfectly safe to say that for such institutions as mills, workshops, etc., the problem of the best method of disposal of the night-soil has been solved.

But all Sanitarians of experience know, that, unless this particular design of latrine can be adapted to the needs of towns, the net amount of sanitary improvement to the community at large will be extremely small. The real question we are interested in, is, can we do something for the towns, which will be cheaper than installing a water carriage system, and which will remove the objections to the hand-removal system ? It is when discussing the question from this standpoint, that the disadvantages of the septic tank latrine became rather apparent.

Firstly, in how many places in India can the two fundamental queries mentioned above be answered in the affirmative ? That is to say, in how many places is there an adequate supply of water and suitable method of disposing of the effluent ? These two conditions, in a dry country like India, where water is extremely scarce, are sufficient to rule out an enormous number of localities.

Secondly, we come to the subject of cost. A septic tank latrine of the cheapest efficient design for a population of, say, two thousand people, would cost Rs. 3,500—4,500. If a special pumping arrangement is necessary, the initial cost and recurring charges would go up considerably.

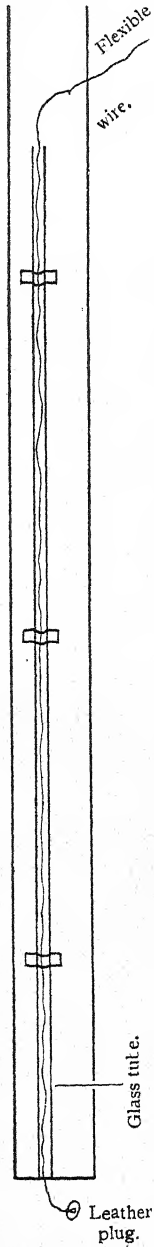
Thirdly, the conditions of working of a latrine open to the public are not so satisfactory as in a regulated community, but this difficulty can, with correct design, be minimised considerably.

Fourthly, the matter of supervision of a latrine is also a somewhat serious problem. Even in a mill, where there are several Europeans, the general sanitary condition of the installation not infrequently leaves very

much to be desired. Granting that it is possible to construct a latrine absolutely correctly designed in all parts, to make it of indestructible material, to have all the flushing arrangements automatic and practically everlasting, a certain amount of daily supervision is necessary. A latrine for the public use would be municipal property, a sweeper would be in charge, with possibly a Sanitary Inspector, instead of a skilled engineer, to appeal to in case of difficulty, so that it is obvious that a septic tank latrine for the public use is not under such favourable circumstances as those attached to mills.

There is, however another side of the picture, namely, that in several places in Bengal, latrines have been constructed in cooly lines, which receive exactly the same sort of treatment as would be accorded to a public latrine. Unfortunately the design of these latrines leaves very much to be desired in the way of simplicity ; they possess complicated flushes and other serious defects, so they are under several disadvantages. But on the whole they are a success. There can be no doubt whatever that they are an immense improvement on the ordinary hand-removal latrine. So that, in spite of a somewhat formidable list of disadvantages against this type latrine for public use, it will be observed that by far the most important of these is the question of water-supply; all the others only require a little careful planning to overcome.

In building septic tank latrines for the public, our advice is, *build them simple and build them large;* if they are not to be an absolute failure, they *must* be simple, and if a latrine is underused, comparatively little harm will result, whereas an overused latrine will give trouble.



Routine examination and care of the tank.

A septic tank latrine cannot be left entirely to itself year in and year out, without certain elementary facts being ascertained concerning its condition. The chemical and physical condition of the effluent should be examined occasionally; in Bengal analyses of filtered and unfiltered effluent are made once a quarter. This appears to be quite sufficient for all practical purposes. The accompanying table is the one that is used for the routine analysis. The chlorine, the four hours' oxygen absorption from potassium permanganate, and the amount of dissolved oxygen remaining, are the chemical tests made use of; the presence of nitrates also is tested for in the filtered effluent. These estimations are comparatively easily carried out and they appear to be sufficient to form an opinion as to the quality of the effluent.

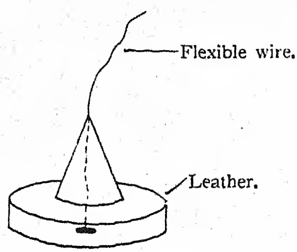


FIG. X (*a*).—Fowler's section taker.

In the Factory Act it is laid down that effluents should be clear, free from fœcal odour, non-putrescible and nitrific-

Chemical Analysis of Effluent from Septic Tank attached to ——————— Jute Mill.

PARTS PER 100,000.

	Chlorides.	4 hours' oxygen.	Dissolved Oxygen remaining. 24 hours.	Dissolved Oxygen remaining. 48 hours.	Nitrates.	Remarks on Physical character and sterilization of effluent.
Latrine No.—						
Unfiltered ...						
Filtered						
Latrine No.—						
Unfiltered						
Filtered						
Latrine No.—						
Unfiltered						
Filtered						
A good effluent should give the following:—						
Unfiltered ...	6	3·5	·25	·1	*nil.*	Slightly hazy but no fœcal odour.
Filtered	6	1·5	·45	25	Present in large quantities.	Clear, slight earthy odour.

Remarks by Sanitary Commissioner :—Quality of your effluent is ———————

Calcutta :

Major, I.M.S.,

Sanitary Commissioner for Bengal.

Dated ——————— *191* .

ation shall be thoroughly commenced. If the effluents do not come up to the standard, they are not pure enough to pass into the river Hooghly. The tests mentioned above are sufficient to see if any effluent fulfils these conditions.

The amount of sludge in the tank should be measured monthly; it should never be allowed to increase more than 12 inches; it is better to run it off after 6 inches have accumulated. As a general rule, the removal of sludge does not require to be done more than once in three or four months. The sludge is best measured by Fowler's section taker, which is an ordinary glass tube provided with a leather cap to be drawn into the end of the tube, *vide* figure X (*a*). To use the apparatus it is lowered into a tank, the leather seal is pulled into position and the apparatus withdrawn; after removal you have a section of the tank contents, including scum, clear fluid and sludge; the latter can be measured in the tube.

Experience of tanks that have been working without cleaning out for years (providing river silt is not allowed to pass into the tank in any quantity) shows, that about 12 inches of sludge at the inlet and 10 inches at the outlet is the maximum usually found. As a matter of fact, there must be a steady increase in the quantity, but the increase, not being very great, is balanced by solidification of lower layers; consequently, even though soundings do not show any increase in the quantity of sludge, it is necessary to open the sludge valve once in three months in order to prevent the consolidation of the lower layers.

The disposal of the sludge has already been referred to. On the whole, it is better to run it into a pit partially filled with sand, the fluid part is allowed to

soak away, and the solid material is buried. Sludge should not be run into a stream, river or pond. Sludge from a septic tank latrine is always, in this country, absolutely odourless. If by chance the amount of silt or clayey material appears to be increasing in any sludge, frequent removal should be undertaken, for if consolidation once takes place, the tank may require to be emptied to get rid of it.

Symptoms of overwork of the Tank.

A tank that is steadily overworked easily discloses the fact on chemical analysis. The results of several tanks which have been shown to be worked very much beyond their capacity are given in the accompanying Table X (*b*). The four hours' oxygen figure shows that the effluent is distinctly unsatisfactory, whilst the chlorine figure demonstrates the fact that the dilution appears to be on the whole about correct. In several of these latrines another factor also has to be recognised, namely, probably the design of the grit chamber is not correct. It is impossible now to settle this point without emptying the tank. In several of these mills new latrines have been built, to accommodate the surplus of users, and an improvement in the quality of the effluent of the old latrine has taken place at once. Our experience is that it is possible to overwork a well-designed, ripe, septic tank up to about 25% above its estimated load, without causing any change in the quality of the effluent; beyond this point falling-off is rather rapid. Probably the whole question depends on the size of the grit chamber; if the grit chamber is large and capable of retaining all the solid masses, the falling-off in the quality of the effluent is comparatively small, but when we reach the point that the solid fœces pass into the body of

the tank, a rapid deterioration takes place. Hence it would appear, that in tanks that are likely to be used

TABLE X (*b*).

SYMPTOMS OF OVERWORK OF THE TANK.

OVER-USED TANK.

Name of installation.	Accommoda-tion on 12-gallon basis.	Population of the mill.	Excess over designed number.	Chlorine figures.	4 Hours' Oxygen test.	REMARKS.
Mill No. I	2,600	4,500	2,100	5·0	9·77	
,, ,, II	2,687	4,200	1,600	4·2	13·41	
,, ,, III	1,833	3,000	1,200	4·6	5·89	
,, ,, IV	1,719	3,100	1,400	4·6	7·14	
,, ,, V	1,862	3,100	1,200	11·0	14·97	Two mills close together. Total population is 3,800.
,, ,, VI	1,812	doubtful	doubtful	4·6	8·03	
Mill No. VII—Tank I	1,937	7,000	2,400	5·5	8·29	
,, ,, II	2,656	...	...	5·0	6·39	
Mill No. IX—Tank I	1,875	6,300	2,500 to 3,000	7·8	11·13	Outsiders use this tank.
,, II	1,875	...	...	3·6	9·32	

very irregularly, it is well to increase the size of the grit chamber from one-eighth to one-sixth of the total capacity.

Starting up a new tank.

In order to start up a new tank the method of procedure should be as follows :—

If there is another septic tank in the immediate neighbourhood, it is advisable to empty, say, 50 or 60 buckets of effluent and sludge into the new tank in order to inoculate it. Chemical experiments show that the ripening of the tank is hastened by this procedure. The tank should be then filled up with water. Supposing it is designed for 2,000 people, a hundred users per diem should be allowed to enter the tank for one week, 200 the second, 300 the third, 400 the fourth. If the effluent at the end of the month is clear and non-offensive, half the total load may be put on at once, and the remaining half should be gradually made to use the latrine during the next two months. By this means a latrine for 2,000 users may be made to work up to its full limit within three months. The effluent will at first be cloudy and very likely fœcal in odour, but it will steadily improve. As a rule, it takes six months before the tank gives its best results.

CHAPTER XI.

THE DISPOSAL OF SEWAGE BY AEROBIC BEDS ONLY.

The Gouripur Installation.

THE installation that has been constructed at the Gouripur Jute Mills near Naihati, is of very special interest, not only because it does not make use of septic tanks and is therefore aerobic from beginning to end, but because slate beds are used in the first stage of the purifying process. The installation was designed by W. J. Dibdin, Esq., of London, the well-known writer on sewage matters. The disposal works consist of, first of all, a collecting or impounding tank, into which the sewage from the latrine is run; 2ndly, slate beds constructed on the well-known lines laid down by the designer; and 3rdly, of a fine contact bed of ordinary pattern. In the original specification a small shallow sand filter was also added, in order to remove as many of the organisms as possible, prior to the passing of the effluent into the river; this was never actually constructed, for a sterilisation process was substituted. Fig. No. XI (*a*) gives a very clear idea of the arrangement of the installation as a whole; further description is hardly necessary. The slate beds were filled up with thin plates made from slate debris, that is to say, ordinary flat pieces of slate which are not of sufficiently good quality to be used for the preparation of roofing slates. This material was

TABLE VII (b).

RESULTS OF ANALYSES OF GAS OBTAINED FROM TANK'S SLUDGE.

Description of Sample.	Composition.	Quantity taken.	Total Gas.	Composition of Gas. CH.	H.	CO.	N.	O.	Amount of Residue.	Remarks.
No. 34 sludge. Left M. H. Kanchrapara, 12-15 P.M., 20th February 1906. Black particles settling readily like tea leaves. Gives H. S. and fœcal smell on warming with acid. Gives skatol test with H. S.O. Mainly "dal bat" residue. One or two diatons present.	About 15 c.c. solids per 100 c.c. Mineral matter in dry residue 36·8%.	Indeterminate.	167·75 c.c. in 14 days. 69·8 c.c. in 38 days. Started 21st February 1906. 20 c.c. gas evolved in first day of experiment.	83·7	6·3	6·9	3·1	...	...	...
No. 49. Gas collected from Shamnagar latrine M.H. at exit end. 10th April 1906, 9-30 A.M. approx.	...	...	Gas taken— Exp. 1—28·8 c.c.	46·5	3·1	5·5	air. 44·9	...	...	Volume of O found in both cases × 4 N in O used makes up residual N.
			Exp. 2—83·2 c.c.	47·0	2·1	4·7	46·62	...	...	
			Calculated without air, 1.	84·4	5·8	9·8	...	...	...	
			Calculated without air, 2.	87·3	3·9	8·7	...	...	...	
E14, 140 c.c., 10 c.c. K1 Crude, Entally Sewage, Kanchrapara tank effluent.	E14 4 hrs.' test 10·57 Albuminoid... 1·42 K1 4 hrs. ... 2·64 Albuminoid... ·18	150 c.c.	...	72·5	14·5	11·6	4·7	...	...	23·3 c.c. taken for analysis 8th May 1906. Experiment started 8th March.
T1. Gas from model septic tank not inoculated with septic sludge originally.	...	...	...	79·3	13·9	9·7	1·1	1·1	...	23·7 c.c. taken for analysis.
T2. Gas from model septic tank inoculated with septic tank sludge.	...	...	...	79·6	15·0	4·8	·8	2·4	...	22·6 taken for analysis.
E14. Crude sewage, Entally ...	4 hours' oxygen test .. 10·57 Albuminoid... 1·42	150 c.c.	...	77·8	4·8	11·7	5·6	...	...	23·6 c.c. taken for analysis on 8th May 1906. Experiment started 8th March.
E203. Crude sewage, Entally ...	4 hours' oxygen test ... 30·2 Albuminoid (av.) 6·0	...	...	73·5	7·5	12·0	4·5	...	...	Started 15th May 1906, began to evolve gas 23rd May. Analysed 9th July, 20 c.c. taken.
Inlet sludge. Simla septic tank ...	Total carbon ...29·87 Total nitrogen...2·41	...	...	74·1	17·9	13·8	*Nil*	*Nil*	...	22·4 c.c. of gas taken for analysis. Much of the gas developed at first was not caught, as the stopper was blown out of the bottle *en route* from Simla, hence possibly some nitrogen escaped.
Outlet sludge. Simla septic tank...	Total carbon ...25·4 Total nitrogen...3·03	...	...	67·2	7·7	25·1 (H.S.)	*Nil*	*Nil*	...	23·5 c. c. taken for analysis.

imported direct from Wales and was split and placed in position by *mistries* here. Square blocks or bars of slate 2 inches high were used as distance pieces.

The working conditions as laid down by Mr. Dibdin were as follows :—The installation was designed for 8,000 people with 12 gallons of water per user. The slate beds were five in number, each measuring roughly 30′×20′×4′. This gives a capacity of 1½ c. ft. of slate material per user per diem. The working or fluid capacity of the bed when filled with slates is 66% of the total capacity when empty.

The fine contact beds were made twice this size, that is to say, 3 c. ft. per user per diem were provided; the material in the contact bed was to pass ½ inch mesh, but all dust was to be removed; finer particles, that is to say, those that pass ¼″ to ⅛″ mesh were allowed to remain.

The whole of the system was to be filled with sewage twice in the day, 8,000 people with a dilution of 12 gallons per user, giving slightly less than twice the total working contents of the 5 beds. These were the conditions as laid down by Mr. Dibdin, and it is only fair to state, that, as these have been very considerably departed from in actual working, he cannot be held responsible for the results.

Several changes were made in the original design :—First of all, when the installation was originally constructed in 1905 it was estimated that 4,000 people per diem would be the maximum number visiting the latrine ; consequently the size of Mr. Dibdin's beds was halved. Subsequently electric light was installed in the mill ; this increased the number of working hours in the day very considerably and necessitated a proportionate increase in the number of hands employed.

The self-registering turnstiles now show that on an ordinary working day the number of users who visit the latrine in order to defœcate is 5,000; besides this, it must be mentioned, that the urinals are not inside the turnstiles, but the urine and flush water passes into the same main drain as the latrine, so that the urine of an additional 3,000 to 5,000 people also has to be disposed of by the installation.

The installation was taken into use sometimes towards the end of 1905 or beginning of 1906, and by the August of 1909, the beds were pretty well choked up with solid material. About this time very great difficulty was experienced in getting rid of the effluent at all. Some 4 or 5 fillings per day became the usual practice; in order to lessen the total quantity of sewage in the day, the water-supply to the latrine was considerably reduced, thereby departing from the 12 gallons dilution laid down by the designer. During the months from August to December 1909 the contents of all the beds were removed, carefully washed up and replaced, so that at the time when this enquiry was commenced (October 1909), the installation was in a very satisfactory condition and is still being worked with considerable success.

A careful gauging of the quantity of water used in the latrine, during the 16 working hours, shows that it amounts to 31,000—35,000 gallons per diem. This divided by 5,000, the number of users, gives a dilution of 6 to 7 gallons per user and not 12 gallons as was originally intended. But in addition to this there is some extra urine. Now it will be remembered that our experimental sewage manufactured at Entally, which forms the basis of comparison for native sewage in this country, contains only the

urine passed at the time of defœcating, that is to say, about 25% of the total in the 24 hours. In most of the installations on the River Hooghly the same conditions obtain, because, either the mill coolies will not go into the latrine to urinate, but void it into the drains, or, urinals are situated in the mill compound, which do not discharge into the septic tanks. In the Gouripur mill, however, the urinals discharge into the main drain, so that the urinary constituents in the Gouripur crude sewage are probably double those of our experimental sewage manufactured at Entally. Chemical analyses of the crude sewage which are given further on in this chapter confirm this statement.

Another point must also be mentioned in discussing the Gouripur crude sewage. The latrine at Gouripur mill is situated some distance from the disposal installation, so, unlike the models already described, the sewage passes down about 100 yards of sewer, before it reaches the impounding tank. In transit a certain amount, but not a very great deal, of breaking up action takes place, hence the remarks that have been made previously, on the characteristics of the sewage entering septic tank latrines apply, though to a somewhat less extent, to this installation. Hard masses form a fair proportion of the crude sewage. A reference to the analyses of the crude sewage in Table XI (*a*) shows this to be the case; it is also apparent that both the chlorine and free ammonia figures are very much higher than those of the Entally sewage, due to the urine being about double in quantity in the Gouripur sewage.

Whatever the dilution of the sewage may be, the whole installation has to dispose of the fœcal discharges of 5,000 individuals and about half of the total urine passed in 24 hours. With slate beds of this size ($30 \times 10 \times 4$)

gives 1·2 c. ft. instead of 1·5 c. ft. per individual per diem, as was laid down by Mr. Dibdin; the fine beds give about 2·4 c. ft. instead of 3 c. ft. per user.

The results of analyses in Table XI (*a*) were obtained with two dosings per diem, the time of contact being rather more than 4 hours in both slate and fine bed. This should be carefully noted. The slate bed was last washed up in February 20th, 1909. By gauging the working capacity of the tank, at the time of taking these samples, it was found to be 1,800 gallons instead of 5,000, so that the effective capacity of the bed had fallen to about 35% of what it should be when clean. The slate bed was, however, very active.

The material in the fine bed had only just been washed up and replaced, its capacity was 5,000 gallons, so that it was obvious that the contents of the slate bed did not nearly fill the fine bed. These conditions of working, particularly the long rest in both beds, must be carefully borne in mind in comparing these results.

It will be observed that the samples are taken in sets of three from collecting tank, slate bed and fine contact bed. The action of the collecting tank levels up the strength of sewage to some extent; but as the amount of water supplied to the latrine is the same for each hour of the day, and as the number of users per hour is very irregular, there is a considerable variation in the strength of the sewage.

The averages of samples are also given in the table for purposes of comparison.

The total percentage purification on 4 hours' oxygen figures gives 81·8%. The slate beds accounting for the purification equal to 60·8%, and the contact beds further increase this to 81·8%.

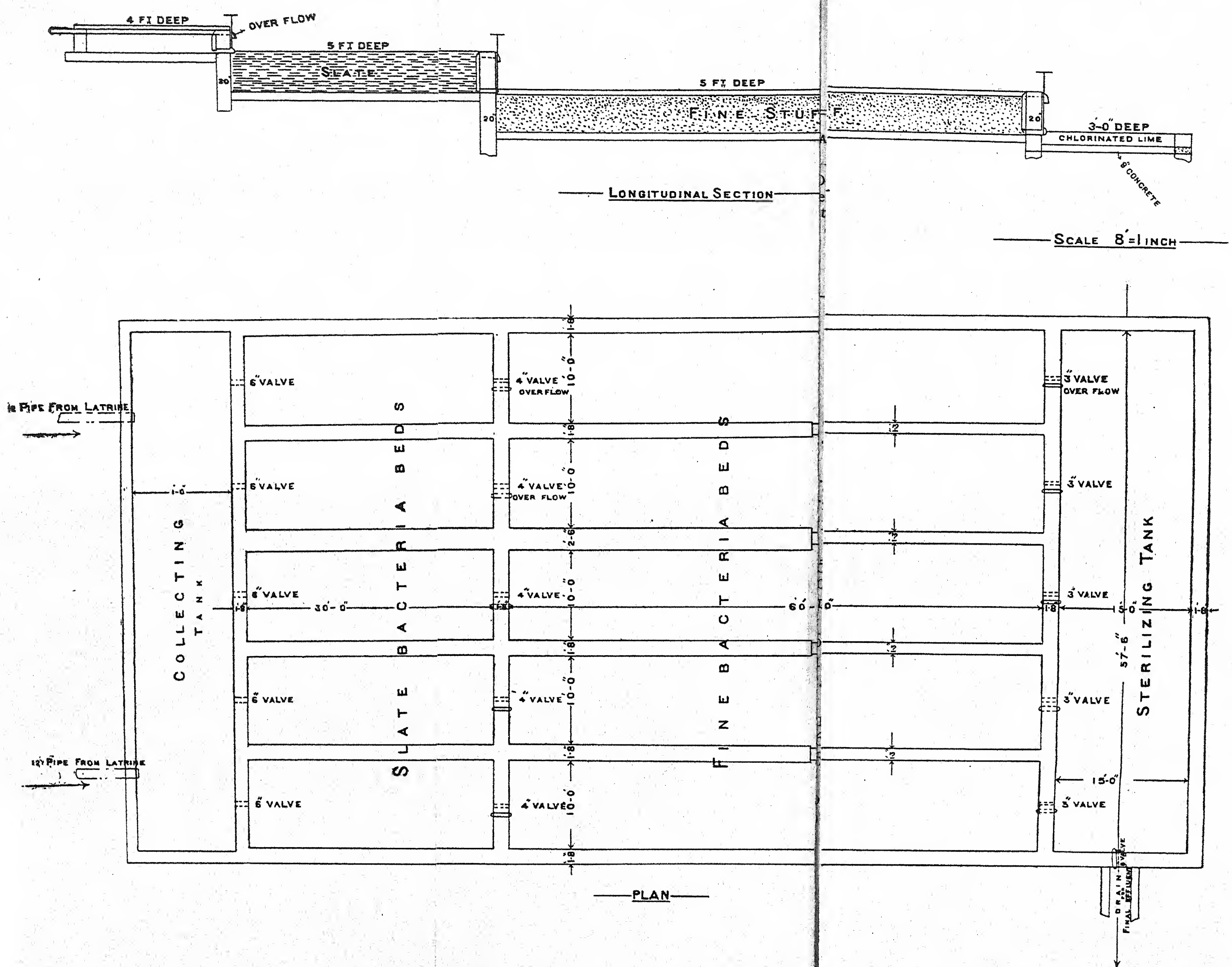


FIG. XI (*a*).—Gouripur Mill Installation.

The amount of colloid material shows a very great reduction in the slate beds; this demonstrates conclusively that the slate beds, as designed by Mr. Dibdin, are undoubtedly efficient in removing a large quantity of material in colloid suspension in the sewage, *when sufficient time is allowed for settlement.* The average figure shows that about 70% of the colloid material in the crude sewage was removed by the slate beds.

The table gives the results of the incubator test. Sufficient has already been said on the irregularity of the results obtained by this test, no further comment need be made on it. But the results obtained from the samples collected on 7th December 1909, bear out the general contention of the unsatisfactory nature of this test; in this instance a clear, odourless, nitrified effluent is, according to this test, more putrescible than the crude sewage.

The nitrogen figures are particularly interesting. There is no doubt that a considerable amount of urea is changed into free ammonia in the collecting tank, the slate beds continue the action and also convert the albumenoid substances into saline ammonia. The amount of free ammonia in the effluent is very great, the average being 9·15 parts per 100,000; this shows how very strong the sewage treated in this installation really is; also it bears out the contention that the amount of urine in the effluent is more than what is usually met with in our experimental sewage. The saline ammonia figure in the final effluent, however, is the one unsatisfactory figure in this table. It demonstrates the fact that the fine contact beds fail to nitrify the whole of the available ammonia; they are, in other words, overworked in this respect. About 55% of free ammonia is nitrified and the remainder will rapidly nitrify when it is diluted

with the water in the Hooghly, but 4 parts per 100,000 of free ammonia is very high for a final effluent.

The amount of nitrates present is quite satisfactory on the whole, but this figure should be higher, whilst that of the saline ammonia should be lower.

The amount of dissolved oxygen taken from dilution 1 in 10 with tap water in 24 hours and 48 hours show that the final effluent, in respect to its oxygen-seizing power, is eminently satisfactory for passing into the river, the amount of oxygen absorbed in these dilutions being very small. It will be observed that there is a considerable variation in the amount of dissolved oxygen absorbed in the various samples of slate bed effluents in the above table; samples taken on 22nd November 1909 and 18th January 1910 seem to be particularly greedy of dissolved oxygen, whereas many others show quite a large amount left unabsorbed even after 48 hours. It should be noted that *it is the sample that contains large quantities of colloid organic matter that absorb dissolved oxygen freely.* The colloid organic figure in the samples named is considerably above the average. There is a sort of parallelism between the amount of dissolved oxygen taken up, and the amouut of colloid organic present in the effluent. This has been noticed in other instances.

It should be stated that the effluent from the fine contact bed is very clear and contains very little suspended matter; it is also free from odour.

A further series of experiments were recommended early in May 1910.

In the instructions for working this installation given by Mr. Dibdin, the following periods of rest were prescribed, 2 hours' rest in the slate bed and 4 hours' in the fine bed, the sewage to be of the dilution of 12 gallons per user.

TABLE XI (a).

GOURIPUR.

Date.	Origin.	Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	3 Minutes' Oxygen value. Before incubation. A.	After incubation. B.	Difference between A & B.	Nitrogen. Saline and free.	Albumenoid Ammonia.	Nitric and Nitrous.	Amount of dissolved Oxy. left, dilution 1 in 10 with tap water. After 24 Hours.	After 48 Hours.	Remarks.
22-11-09	Collecting Tank ..	8·0	10·00	3·64	6·36	3·76	3·96	·20	5·54	1·67	*Nil*	*Nil*	*Nil*	
22-11-09	Slate Bed No. 2 ..	8·0	6·00	2·73	3·27	2·57	2·90	·33	11·55	·63	*Nil*	*Nil*	*Nil*	
22-11-09	Fine Bacteria Bed ..	8·0	2·37	1·19	1·18	·91	1·17	·26	3·47	·43	·53	·521	·416	
7-12-09	Collecting Tank ..	8·0	12·22	3·03	9·19	4·98	5·13	·15	5·55	1·79	*Nil*	*Nil*	*Nil*	
7-12-09	Slate Bed ..	7·2	3·89	1·91	1·98	1·58	2·03	·45	16·00	·87	*Nil*	·26	·08	
7-12-09	Fine Bacteria Bed ..	7·6	2·08	1·42	·66	·83	1·13	·30	3·38	·45	2·77	·48	·33	
15-12-09	Collecting Tank ..	8·0	12·46	3·14	9·32	5·38	5·87	·49	6·15	2·07	*Nil*	*Nil*	*Nil*	
15-12-09	Slate Bed ..	7·8	4·61	2·47	2·14	1·79	2·03	·24	8·67	·75	*Nil*	·30	·08	
15-12-09	Fine Bacteria Bed ..	7·8	2·09	1·46	·63	·84	·96	·12	3·69	·42	2·46	·57	·32	
5-1-10	Collecting Tank ..	9·0	13·20	3·86	9·34	6·00	6·50	·50	5·20	1·73	*Nil*	*Nil*	*Nil*	
5-1-10	Slate Bed ..	7·6	3·06	1·77	1·29	1·82	1·90	·08	4·92	·66	*Nil*	·47	·35	
5-1-10	Fine Bacteria Bed ..	7·8	1·29	1·14	·15	·61	·80	·19	3·38	·31	2·16	·52	·50	
12-1-10	Collecting Tank ..	8·2	8·16	1·91	6·25	3·58	4·20	·62	3·38	1·51	*Nil*	*Nil*	*Nil*	
12-1-10	Slate Bed ..	7·8	3·22	1·58	1·64	1·07	1·50	·43	6·15	·67	*Nil*	·44	·28	
12-1-10	Fine Bacteria Bed ..	8·0	1·84	·92	·92	·66	·90	·24	2·31	·34	3·23	·54	·49	
18-1-10	Collecting Tank ..	8·4	17·34	4·37	12·97	6·35	6·96	·61	5·20	1·87	*Nil*	*Nil*	*Nil*	
18-1-10	Slate Bed ..	8·0	7·96	3·59	4·37	2·79	3·25	·46	1·55	1·13	*Nil*	·01	*Nil*	
18-1-10	Fine Bacteria Bed ..	7·8	3·28	2·81	·47	1·55	1·71	·16	5·93	·72	2·97	·55	·08	
25-1-10	Collecting Tank ..	7·4	8·20	2·11	6·09	3·40	4·00	·60	2·77	1·63	*Nil*	*Nil*	*Nil*	
25-1-10	Slate Bed ..	7·0	3·22	1·66	1·56	1·00	1·30	·30	5·20	·58	*Nil*	·37	·24	
25-1-10	Fine Bacteria Bed ..	7·2	1·84	1·29	·55	·60	·80	·20	4·73	·30	2·34	·53	·46	
Average of Collecting Tanks		**8·14**	**11·65**	**3·15**	**8·50**	**4·78**	**5·23**	**·45**	**4·82**	**1·75**	*Nil*	*Nil*	*Nil*	
„ „ Slate Beds ..		**7·6**	**4·56**	**2·20**	**2·36**	**1·80**	**2·13**	**·33**	**[illegible]·15**	**·75**	*Nil*	**·26**	**·14**	
„ „ Fine Bacteria Beds ..		**7·7**	**2·11**	**1·47**	**·64**	**·85**	**1·06**	**·21**	**3·98**	**·42**	**2·35**	**·53**	**·37**	
Percentage purified of Slate Bed ..			**60·8%**	..	..	..	..	..	..	**57%**	..	..	..	
„ „ „ Both ..			**81·8%**	..	..	..	..	..	..	**76%**	..	..	..	

An endeavour was made to see what results could be obtained from the installation worked exactly on the lines laid down by the designer. There was, however, one very small difference, *viz.*, that if the installation had been working with clean beds, 2 fillings per 24 hours would have sufficed to have disposed of the total sewage in 24 hours. At this time, the working capacity of the beds had considerably decreased, so that 3 fillings per 24 hours were required, but the periods of contact were kept as above. The results are given in Table XI (*b*). The following points in these analyses should be carefully noted :—

(1) Of course, the sewage is now comparatively dilute, it being a true 12-gallon sewage. Further, at this time of the year there is probably less urine in the sewage than there was in November and December, when the results given in Table XI (*a*) were obtained. In hot weather the quanity of urine passed both by Europeans and natives alike is considerably diminished.

(2) The most striking point to be noticed in this table is the great falling-off in the amount of purification carried out in the slate beds. This figure should be compared with the results given in Table XI (*a*). It will be observed that in the latter something like 60% of the total purification, calculated on the 4 hours' oxygen figure, was obtained, and also an enormous reduction in the amount of colloid. In these recent experiments with dilute sewage, the purification effected by the slate bed is very small, and there is only a slight reduction in the colloid impurity. This is due to two causes :—

(*a*) The length of time in the slate beds is now 2 hours, whereas in the results given in Table XI (*a*), it was over 4 hours (as one of the beds remained full for part of the night, it is extremely probable, owing to

the laziness of the sweepers, that the sewage remained as long as 6 hours in contact with the slates).

(*b*) The bed used in the work described in Table XI (*a*) was old and was probably very active; the one recently experimented on was a clean bed and had probably not reached any very advanced state of activity.

These two factors seem to be responsible for the great decrease in the purification obtained in the slate beds.

(3) The same fact should be noticed in Table XI (*b*) as existed in XI (*a*), *viz.*, that although nitrification has gone on to a considerable extent, there still remains more saline and free ammonia than should be present in a good final effluent.

Further experiments were tried with a sewage that works out at 9 gallons per user. Two series of results are given, *viz.*, those when the beds were filled 3 times in the 24 hours, and another when one filling was given. The length of contact was the same as in the previous experiment, *viz.*, 2 hours in the slate bed and 4 hours in the fine. The results are given in Tables XI (*c*) and (*d*). They only differ slightly from the results given in Table XI (*b*), in the respect that the sewage is somewhat more concentrated. Exactly the same defects are obvious in Tables XI (*c*) and (*d*), *viz.*, the purification in the slate beds both as regards 4 hours' oxygen and colloid material is very slight, and the final effluent contains too much colloid material and free ammonia and too little nitrates. The difference observed between Tables XI (*c*) and (*d*), that is to say, between a bed with 3 doses in 24 hours and that with one, is not very marked in respect to the quantity of nitrates, albumenoid ammonia and saline ammonia. But there is a very considerable falling-off in quality in the 4 hours' oxygen figure, when 3 fillings are given

TABLE XI (*b*).

GOURIPUR THREE FILLINGS 12-GALLON SEWAGE.

DATE.	ORIGIN.	CHLORINE.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	NITROGEN.			AMOUNT OF DISSOLVED OXYGEN LEFT.		REMARKS.
						Saline and free.	Albumenoid Ammonia.	Nitric and Nitrous.	After 24 Hours.	After 48 Hours.	
25-5-10	Collecting Tank ..	4·0	5·00	1·26	3·74	2·46	·89	*Nil*	*Nil*	*Nil*	
do.	Slate Bed ..	4·2	4·27	1·08	3·19	4·16	·71	*Nil*	*Nil*	*Nil*	
do.	Fine Bacteria Bed ..	4·0	·82	·82	*Nil.*	1·41	·21	·56	·59	·55	
26-5-10	Collecting Tank ..	3·6	6·01	1·74	4·27	2·21	·93	*Nil*	*Nil*	*Nil*	
do.	Slate Bed ..	3·8	5·84	1·74	4·10	3·20	·85	*Nil*	*Nil*	*Nil*	
do.	Fine Bacteria Bed ..	3·0	1·43	1·33	·10	1·23	·35	·66	·48	·29	
Average of Collecting Tanks	..	**3·8**	**5·50**	**1·50**	**4·00**	**2·33**	**·91**	*Nil*	*Nil*	*Nil*	
Average of Slate Beds	..	**4·0**	**5·05**	**1·41**	**3·64**	**3·68**	**·78**	*Nil*	*Nil*	*Nil*	
Average of Fine Bacteria Bed	..	**3·5**	**1·12**	**1·07**	**·05**	**1·32**	**·28**	**·61**	**·53**	**·42**	

TABLE XI (*c*).

GOURIPUR THREE FILLINGS 9-GALLON SEWAGE.

DATE.	ORIGIN.	CHLORINE.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	NITROGEN.			AMOUNT OF DISSOLVED OXYGEN LEFT.		REMARKS.
						Saline and free.	Albumenoid Ammonia.	Nitric and Nitrous.	After 24 Hours.	After 48 Hours.	
2-6-10	Collecting Tank ..	5·4	10·70	3·59	7·11	4·73	1·74	*Nil*	*Nil*	*Nil*	
2-6-10	Slate Bed ..	5·2	10·27	3·35	6·92	5·94	1·49	*Nil*	*Nil*	*Nil*	
2-6-10	Fine Bacteria Bed ..	5·2	5·94	2·77	3·17	4·16	·74	·57	*Nil*	*Nil*	
3-6-10	Collecting Tank ..	4·8	9·73	3·59	6·14	3·20	1·81	*Nil*	*Nil*	*Nil*	
3-6-10	Slate Bed ..	4·6	8·97	3·46	5·51	4·00	1·45	*Nil*	*Nil*	*Nil*	
3-6-10	Fine Bacteria Bed ..	4·6	4·21	1·62	2·59	1.23	·69	·32	·34	*Nil*	
Average of Collecting Tanks	..	**5·1**	**10·21**	**3·59**	**6·62**	**3·96**	**1·77**	*Nil*	*Nil*	*Nil*	
Average of Slate Beds	..	**4·9**	**9·62**	**3·40**	**6·21**	**4·97**	**1·47**	*Nil*	*Nil*	*Nil*	
Average of Fine Bacteria Beds	..	**4·9**	**5·07**	**2·19**	**2·88**	**2·69**	**·71**	**·44**	**·17**	*Nil*	

instead of 1. Still it is amply demonstrated, that, the difference between these sets of results, is not anything like sufficient to make it necessary to provide sufficient contact beds to allow of only one contact per 24 hours.

The water-supply in the sewage was further reduced in order to see if results could be obtained similar to those given in Table XI (*a*). A sewage which was something between 5 and 6 gallons dilution per user was made, and was dosed into 3 separate beds, giving 1, 2 and 3 fillings per 24 hours respectively, into each bed. On account of the poor results obtained in the foregoing analyses the length of rest in the slate bed was doubled, so that 4 hours' contact in both slate beds and fine beds was allowed. The average results only are given in Table XI (*e*). The sewage is now a very strong one and approximates to the Entally experimental sewage when "partially mixed." With this very strong sewage only one filling per day could be expected to give a good result, because in one filling is contained all the discharge of one-fifth of the number of users. Of course, if the installation as a whole was worked with this strength of sewage, the quantity would be so small that only one filling per bed per diem would be required. There was no nitrate present, in the results obtained from 2 to 3 fillings, showing the beds are greatly overworked.

These results (obtained with one filling) are extremely interesting when compared with the results given in Tables XI (*b*), (*c*) and (*d*). It will be observed that due to the increase in the length of contact in the slate beds, there is very considerable improvement in the purification effected by these beds, both as regards the 4 hours' oxygen and amount of colloids. Of course, the amount of saline ammonia is still too great in the final effluent, and the amount of nitrates is also

deficient, but, considering the concentration of the sewage, there can be no doubt whatever, that a decided improvement has been brought about by increasing the rest in the slate beds. With a dilute sewage of 12 gallons per user, and a 4 hours' rest in the slate beds a very satisfactory effluent is obtained, *vide* the results given below. Table XI (*f*).

As a matter of fact, the results given in Table XI (*e*) would have been better if the beds had been allowed to work with this strength of sewage for a month prior to the samples being taken, as the later samples are considerably better than the earlier ones, particularly in respect to the quantity of nitrates produced. They, however, do not approach in excellence to those given in Table XI (*a*).

Reviewing the whole of these analyses, certain points stand out conspicuously. They are:—

(1) It is perfectly evident that a very satisfactory result can be obtained from this design of installation whether a concentrated or a more dilute sewage is used. On the whole, we are inclined to think that the optimum dilution, from the point of view of greatest chemical efficiency, is the one suggested by Mr. Dibdin, *viz.*, 12 gallons per user. But there are several practical objections to this: (*a*) When the beds begin to choke up (a subject which will be presently dealt with), 2 fillings per diem for the whole installation does not dispose of the total quantity of sewage. Hence, 3 fillings per day and even more have to be resorted to. This greatly increases the difficulty of working the installation. Consequently, we consider that a 9-gallons dilution is better, because, it would not make it any more difficult to obtain a satisfactory final effluent, and the smaller volume of sewage in the 24 hours, would

TABLE XI (*d*).

GOURIPUR ONE FILLING 9-GALLON SEWAGE.

DATE.	ORIGIN.	CHLORINE.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	NITROGEN. Saline and free.	NITROGEN. Albumenoid Ammonia.	NITROGEN. Nitric and Nitrous.	AMOUNT OF DISSOLVED OXYGEN LEFT. After 24 Hours.	AMOUNT OF DISSOLVED OXYGEN LEFT. After 48 Hours.	REMARKS.
1-6-10	Expt. Collecting Tank ..	5·2	6·21	2·59	3·62	3·78	1·22	*Nil*	*Nil*	*Nil*	
1-6-10	Do. Slate Bed ..	5·8	8·18	2·90	5·28	4·89	1·71	*Nil*	*Nil*	*Nil*	
1-6-10	Do. Fine Bacteria Bed ..	5·0	1·96	1·75	·21	1·89	·67	·51	·44	*Nil*	
2-6-10	Do. Collecting Tank ..	5·8	11·24	3·78	7·46	5·44	1·99	*Nil*	*Nil*	*Nil*	
2-6-10	Do. Slate Bed ..	6·0	9·94	3·24	6·70	5·20	1·46	*Nil*	*Nil*	*Nil*	
2-6-10	Do. Fine Bacteria Bed ..	5·4	3·56	1·51	2·05	2·60	·64	·87	·33	*Nil*	
3-6-10	Do. Collecting Tank ..	6·2	13·51	4·21	9·30	4·52	2·01	*Nil*	*Nil*	*Nil*	
3-6-10	Do. Slate Bed ..	5·8	11·89	3·78	8·11	4·73	1·76	*Nil*	*Nil*	*Nil*	
3-6-10	Do. Fine Bacteria Bed ..	5·0	4·75	1·83	2·92	2·08	·70	·38	·22	*Nil*	
Average of Collecting Tanks ..		**5·7**	**10·32**	**3·52**	**6·79**	**4·58**	**1·74**	*Nil*	*Nil*	*Nil*	
Average of Slate Beds ..		**5·8**	**10·00**	**3·30**	**6·69**	**4·94**	**1·64**	*Nil*	*Nil*	*Nil*	
Average of Fine Bacteria Beds ..		**5·1**	**3·42**	**1·69**	**1·72**	**2·19**	**·67**	**·58**	**·33**	*Nil*	

TABLE XI (e).

GOURIPUR 6-GALLON SEWAGE WITH 4 HOURS' CONTACT IN SLATE BEDS.

Origin.	Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	Nitrogen.			Amount of dissolved Oxygen left.		Remarks.
					Saline and free.	Albumenoid Ammonia.	Nitric and Nitrous.	After 24 Hours.	After 48 Hours.	
One Filling—										
Average of Collecting Tanks ..	6·60	15·87	4·17	11·7	6·77	1·96	*Nil*	*Nil*	*Nil*	
Average of Slate Beds ..	6·46	8·77	2·86	5·93	6·56	1·46	*Nil*	*Nil*	*Nil*	
Average of Fine Bacteria Beds ..	6·53	4·34	1·87	2·46	3·25	·81	1·20	·18	*Nil*	
Two Fillings—										
Average of Collecting Tanks ..	6·80	24·21	5·67	17·87	6·10	2·14	*Nil*	*Nil*	*Nil*	
Average of Slate Beds ..	6·53	9·83	3·13	6·66	8·71	1·57	*Nil*	*Nil*	*Nil*	
Average of Fine Bacteria Beds ..	6·73	5·36	2·16	2·53	5·45	1·06	Trace	·177	*Nil*	
Three Fillings—										
Average of Collecting Tanks ..	6·93	20·69	5·13	15·26	5·35	2·37	*Nil*	*Nil*	*Nil*	
Average of Slate Beds ..	6·73	14·31	3·56	10·73	12·46	2·15	*Nil*	*Nil*	*Nil*	
Average of Fine Bacteria Beds ..	6·66	7·61	2·47	5·14	9·32	1·24	*Nil*	*Nil*	*Nil*	

allow a certain amount of margin for falling-off in the capacity of the beds, without having to resort to 3 fillings per diem. (*b*) Not many places in India can supply 12 or even 9 gallons per user.

(2) Another point which is amply demonstrated by the whole of these results is, that it is absolutely necessary, when dealing with an unmixed or partially mixed sewage, to give a longer contact than 2 hours in the slate beds. With a 9-gallons dilution 4 hours in the slate beds should be allowed, for the above analyses have shown that a satisfactory final effluent can *only* be obtained if the slate beds do a fair share of the purification.

(3) In spite of the fact that the beds at Gouripur have been worked in many different ways, we have never succeeded in getting a satisfactory nitrification of the saline ammonia. The quantity of saline ammonia in the Gouripur crude sewage is, in reality, not unusually great, as compared with European conditions, for only about 50—66% of the total urine, passed in 24 hours, finds its way into the sewage. It would, therefore, appear that the power of nitrifying ammonia was in some way deficient in the fine contact beds, and, either these are too small, or the quality of the material in them is not satisfactory. We consider that the last of these two suppositions is probably correct. The material used in the contact beds in Gouripur is quartz gravel, the particles vary from ½" to ⅛" in size. This is very inferior to hard furnace clinker of similar size, on account of its smooth surface; we consider that the want of nitrifying power is not so much due to the beds being insufficient in size, as to the fact that the quality of the material they contain is probably worse than it should be. Therefore, we think, it may be said that if first class

material had been obtained, a very satisfactory purification with 3 c. ft. of material per user, or 9 users per c. yd., would have resulted.

This completes the study of the chemical results obtained on the installation. Before closing this Chapter there is another point which requires discussion, that is, the rapidity with which the fluid capacity of the slate beds decreases. It has already been mentioned that within a period of about 3 years the whole of the installation had to be washed up once, and portions of it twice. Careful record was kept as to the date on which the beds were again taken into work after this operation. After a few months' working the fluid capacity of the beds was gauged. The results are given in Table XI (*g*). The total capacity of the empty tank is 7,500 gallons; when filled with slates it is 66% of this, *viz.*, 5,000 gallons. The figures given here are extremely instructive. One bed that has worked for 2 years and 2 months has reduced its working capacity from 66% to 15·5%; a bed that has only been working 4½ months has lost about half its working capacity, that is to say, it is now 30% instead of 66%. This, to our mind, constitutes the serious defect in the whole of the installation. Mr. Dibdin has probably never in his life seen a 5 or a 12-gallon *fresh sewage*, and such a commodity is altogether different from the homogeneous mixture that one is accustomed to meet with in Europe. Whether the dilution be 5, 9 or 12 gallons per user, probably does not alter the rate at which the beds sludge up, because there is practically no doubt, that the rapid falling-off in capacity is due to the hard masses of fœces and not to the fine material, that settles as a layer on the slates. If all the solid material, retained by the slate beds, was deposited in a fine layer, "digestion" would reduce the

TABLE XI (*g*).

LOSS IN CAPACITY OF GOURIPUR SLATE BEDS.

	When taken into use after washing up.	Gauged capacity. 24th May, 1910.	Percentage capacity.
Bed I	March 15th, '08 ..	1,208 gals.	16·5% in 2 years—2 1/3 months.
Bed II	February 20th, '09 ..	1,510 gals.	21·5% in 1 year—3 months.
Bed III	January 30th, '10 ..	3,473 gals.	46·3% in less than 4 months.
Bed IV	January 15th, '10 ..	2,114 gals.	30·0% in more than 4 1/2 months.
Bed V	December 25th, '09 ..	3,474 gals.	46·5% in 5 months.

Capacity of the empty tank, is 7,500 gals.; when filled with slates, it is 66% of this, *viz.*, 5,000 gallons.

bulk of this, and the residuum could be got rid of by flushing the slates with a hose; but no arrangement whatever can possibly cope with solid masses of fœcal material, which block up whole spaces at a time and which no amount of flushing will dislodge. From the observations given in Table XI (*g*), we consider that even if the beds are worked on exactly the lines laid down by Mr. Dibdin, the slate will require removing and cleansing once in 2 years. This is, of course, a very serious business and is the great defect of the installation as a whole. If a thoroughly mixed sewage, such as is obtained at the end of a long sewer, were used, washing up would only be necessary once in 5 years or possibly not at all.

CHAPTER XII

THE DISPOSAL OF SEWAGE BY AEROBIC BEDS ONLY.—(*Contd.*)

Dr. Fowler's Experimental Installation.

WHEN Dr. Fowler was in Bengal, he wished to investigate the behaviour of an oriental sewage when subjected to aerobic treatment only, consequently a small experimental installation was started consisting of a series of contact beds without any septic tank. This was fed with our experimental sewage. The reasons as given by himself for the selection of this design were, that, septic tanks in Europe had given trouble where considerable variation in the rate of flow was observed; during the period of minimum flow the stagnation in the tank frequently gave rise to a great deal of nuisance. As this difficulty would probably exist to a great extent in the small installation in Bengal, it seemed desirable to ascertain if the purely aerobic system, which is not affected by variation in the flow, would give better results. The description of the installation given by Dr. Fowler himself in his report is quoted below :—

" The object of the installation being to study the composition and behaviour of native sewage under strictly defined conditions, a small 2-seated latrine was built in the vicinity of the experimental plant,

from which it was possible to obtain the liquid and solid excreta of a specified number of users.

"The experimental plant consisted essentially of the following parts, *viz.* :—

A. Receiving tank.

B. Primary contact beds.

C. Secondary beds to be used either as contact beds or continuous filters.

D. Sand filters.

"The receiving tank A1 consisted of a rectangular box of galvanized iron. The dimensions of this tank were 2 ft. by 2 ft. 6 ins. deep, the water content being 8 c. ft., or 50 gallons : equivalent to an assumed daily sewage contribution of 5 gallons per head from 10 persons.

"This tank was intended to impound the daily sewage discharge from 10 persons as described, and to be discharged when full, by hand through a conical vertical plug in the bottom, into an inlet or feed channel, from which it can be admitted at will by means of conical wooden plugs to each of the primary contact tanks or beds in succession.

"The primary contact beds or tanks were 5 in number, each 3 ft. 6 ins. by 3 ft. 6 ins. by 2 ft. 9 ins. deep (inside dimensions).

"The filling material occupied the whole interior space of each tank to a depth of 2 ft. 3 ins.

"These primary beds were originally intended to operate on the principle of Mr. Dibdin's recently devised aerobic slate beds, and if slate was unprocurable, it was proposed to use thin flat tiles separated by wooden laths as distance pieces. It was not found possible to obtain either slates or this form of tiles. It was necessary, therefore, to make use of ordinary bricks

broken in half, set carefully at approximately equal intervals of about an inch or less from each other, and separated horizontally by wooden "slats" about half an inch in thickness. Tanks Numbers 2, 4 and 5 were thus filled. Tank No. 3 was similarly filled with hard broken blue brick, each broken into four parts, while tank No. 1 was filled with superimposed half pipes. This last filter approached most nearly to the requirements of offering the maximum surface combined with the maximum water-holding capacity, but such material would be very costly to use in practice.

"Each tank was provided with an iron stopcock by which the contents could be discharged into the corresponding secondary beds, and from which at intervals, if necessary, the accumulated deposit could be sluiced out.

"The secondary beds or tanks were constructed of the same size as the primary tanks and of galvanized iron. The filtering material varied in the different beds as follows, the layers being described from the top downwards :—

1A.

3 inches clinker rejected by 1/16 inch pass ⅛ inch.
3 inches clinker rejected by ⅛ inch pass ¼ inch.
6 inches clinker rejected by ¼ inch pass ½ inch.
6 inches clinker rejected by ½ inch pass 1 inch.
9 inches clinker rejected by 1 inch pass 1½ inch.

2A.

12 inches clinker rejected by ⅛ inch pass ¼ inch.
12 inches clinker rejected by ¼ inch pass 2 inches.
3 inches clinker above 2 inches.

3A.

18 inches clinker rejected by ⅛ inch pass ¼ inch.
6 inches clinker rejected by ¼ inch pass 2 inches.
3 inches clinker above 2 inches.

4A.

3 inches garden soil.
15 inches clinker rejected by ⅛ inch pass ¼ inch.
6 inches clinker rejected by ¼ inch pass 2 inches.
3 inches clinker above 2 inches.

5A.

3 inches Indian patent stone fines below ⅛ inch, excluding dust.
15 inches Indian patent stone rejected by ⅛ inch pass ¼ inch.
6 inches Indian patent stone rejected by ¼ inch pass 2 inches.
3 inches Indian patent stone above 2 inches.

"The final sand filter tanks (referred to as 1B, 2B, 3B, 4B and 5B) were constructed in concrete, sand from the waterworks, being placed into a depth of about 1 ft. over about 3 ins. of broken brick. The sand filters discharged into an adjacent small pond. The sand filters were not brought into operation till the rest of the installation had been some time in operation. The water for the installation was pumped by hand from a larger pond or "tank" near by.

"A sample of this water was analysed with the following results:

	Parts per 100,000.
OXYGEN ABSORBED—	
Four hours' test	·45
Three minutes' test	·19
NITROGEN—	
Ammoniacal	·006
Albumenoid	·026
Nitrous and nitric	·013
CHLORINE—	4·2

The routine of operation was as follows :—

"At 7 A.M. every morning from the 24th February to 24th April 1906, the excreta from five persons

was placed in the receiving tank which was filled up with water (the dilution per head being thus 10 gallons), and its contents thoroughly mixed and discharged on to one of the primary filters. One filter was filled every day in turn. After two hours' contact the contents of the primary filter were allowed to run slowly on to the secondary filter, six hours being occupied in the operation.*

"It was originally intended that the secondary filters should be worked as continuous percolating beds, but in order to get the whole of the material "matured" and to prevent the formation of channels in the material, the exit stopcocks were kept closed and they were allowed to fill up and act as contact-filters. As it was found that the greater part of the purification was effected by the secondary beds, when thus worked, this method of operation was continued. The effluent discharged from them at 3 P.M. was, however, allowed to flow continuously through the sand filters, about two hours being taken for this operation."

The average results of the treatment, without the sand filters, with a 10-gallon sewage are given in a tabular form below in Table XII (*a*).

On April the 24th, 1906, the fœces and urine of 10 individuals instead of 5 was taken in order to make the crude sewage, that is to say, the sewage was changed to a 5-gallons dilution. The stronger sewage was applied to the beds in precisely the same way as the former dilute mixture. The results obtained in the months of April and May were fairly satisfactory; but shortly after this several accidents happened, which disturbed the working arrangement. First of all, a change took place in the staff, several unsatisfactory

* These times were soon changed to 4 hours' contact in both beds.

TABLE XII (*a*).

AVERAGE RESULTS OBTAINED FROM DR. FOWLER'S INSTALLATION (10-GALLON SEWAGE), APRIL AND MAY 1906.

Origin.	Chlorine.	4 Hours' Oxygen Test.			Percentage of Purification.			Remarks.
	Crude.	Crude.	Brick bed.	Fine bed.	In brick bed.	In fine bed.	Total.	
Filter 1	6·4	8·42	8·01	2·49	4·8	60·4	62·3	
Do. 2	6·6	8·75	7·62	3·51	20·0	50·0	59·8	
Do. 3	7·0	9·01	8·13	3·36	12·3	51·1	57·2	
Do. 4	6·9	8·75	7·66	2·32	10·0	63·1	64·5	
Do. 5	6·2	9·74	7·76	3·00	22·6	55·8	65·9	

The results are not anything very striking. They show that the coarse beds are giving very little purification at present, but then they are very new; the contact beds, however, give quite a fair reduction of organic matter.

servants were in charge of the installation, so that the working was extremely erratic; 2ndly, the rainy season commenced in Calcutta, so that the empty tanks very frequently received a large quantity of rain water which did not run away; consequently as the sewage passed from the collecting tank into the coarse bed, and from the brick bed into the fine bed, it was further diluted with rain water. The chlorine figures taken at this period show this. It has, therefore, been decided to discard the whole analyses of the months of August, September and October of 1906. Some time in October 1906, the old servant at present in the laboratory was appointed, and since this time little or no variation has occurred in the manufacture of the crude sewage. The average results of analyses made during November and December 1906 are given below (Table XII (*b*)), and can be relied on as correct.

By this time the installation has been working a little over twelve months. It will be observed that the effluent from the coarse beds in Table XII (*b*) is much superior to that given in Table XII (*a*), in spite of the doubling of the strength of the sewage; this is due to the increased length of contact in the coarse beds; these beds are now giving what may be called a fair purification. The fine beds still perform a greater share of the work.

For the years 1907 and 1908, I was absent from Bengal. During the whole of this period, however, the installation was kept going as described above. In April 1910, the study of the installation was resumed and the results of analyses obtained are given in Table XII (*c*).

Unfortunately at this time the crude sewage was for some reason (probably from defective mixing)

TABLE XII (*b*).

AVERAGE RESULTS OBTAINED FROM DR. FOWLER'S INSTALLATION (5-GALLON SEWAGE), NOVEMBER AND DECEMBER 1906.

ORIGIN.	CHLORINE.	4 HOURS' OXYGEN TEST.			PERCENTAGE OF PURIFICATION.			REMARKS.
	Crude.	Crude.	Brick bed.	Fine bed.	In brick bed.	In fine bed.	Total.	
Filter 1	9·5	26·97	14·3	3·49	43·2	75·6	87·0	
Do. 2	8·8	25·48	14·37	4·62	43·6	67·8	81·8	
Do. 3	9·0	24·73	13·18	5·08	46·7	61·4	79·4	
Do. 4	8·8	27·84	15·06	5·19	45·9	65·5	81·3	
Do. 5	8·1	25·92	13·77	4·03	46·8	70·7	84·0	

TABLE XI (*f*).

GOURIPUR 12-GALLON SEWAGE, 4 HOURS' REST IN SLATE BEDS.

DATE.	ORIGIN.	CHLORINE.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	NITROGEN.			AMOUNT OF DISSOLVED OXYGEN LEFT.		REMARKS.
						Saline and free.	Albumenoid Ammonia.	Nitric & Nitrous.	After 24 Hours.	After 48 Hours.	
	Collecting Tank ..	4·0	5·6	1·50	4·1	2·36	·90	*Nil*	*Nil.*	*Nil*	
	Slate Bed ..	4·0	3·1	1·1	2·0	4·01	·64	*Nil*	·31	*Nil*	
	Fine Bacteria Bed ..	4·2	·8	·76	·04	1·20	·25	·84	·53	·48	

TABLE XII (c).

FOWLER'S INSTALLATION (SEWAGE MIXED).

Date.	Origin.	Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	Nitrogen. Saline and free.	Nitrogen. Albumenoid Ammonia.	Nitrogen. Nitric and Nitrous.	Amount of Dissolved Oxygen Left. After 24 Hours.	Amount of Dissolved Oxygen Left. After 48 Hours.	Remarks.
11-4-10	Tank No. 3 Crude ..	8·2	19·0	..	..	..	..	..	..	..	
11-4-10	do. do. Brick bed ..	9·0	14·50	5·0	9·50	2·95	2·12	*Nil*	1 in 10 ·03	*Nil*	
11-4-10	do. do. Contact bed ..	9·0	4·80	2·40	2·40	·49	·83	2·34	*Nil*	*Nil*	
12-4-10	Tank No. 4 Crude ..	8·0	18·57	..	..	..	..	..	..	..	
12-4-10	do. do. Brick bed ..	7·8	13·17	4·76	8·41	2·83	1·94	*Nil*	*Nil*	*Nil*	
12-4-10	do. do. Fine bed ..	7·6	4·95	2·64	2·31	·49	·84	2·19	*Nil*	*Nil*	
13-4-10	Tank No. 5 Crude ..	8·0	15·94	..	..	..	..	..	..	..	
13-4-10	do. do. Brick bed ..	7·6	11·51	4·05	7·46	2·46	2·00	*Nil*	1 in 20 *Nil*	*Nil*	
13-4-10	do. do. Fine bed ..	7·4	3·57	1·58	1·99	·54	·77	2·17	·31	*Nil*	
14-4-10	Tank No. 1 Crude ..	7·8	15·39	..	..	..	..	..	.	..	
14-4-10	do. do. Brick bed ..	7·4	11·41	4·46	6·95	2·58	2·03	*Nil*	*Nil*	*Nil*	
14-4-10	do. do. Fine bed ..	7·4	3·37	1·58	1·79	·49	·74	2·46	·32	*Nil*	
15-4-10	Tank No. 2 Crude ..	8·2	16·25	..	..	..	..	..	..	..	
15-4-10	do. do. Brick bed ..	8·0	11·58	4·60	6·98	2·58	2·06	*Nil*	*Nil*	*Nil*	
15-4-10	do. do. Fine bed ..	7·6	3·12	1·06	2·06	1·66	·67	1·29	·34	*Nil*	
	Average of Crude ..	**8·0**	**17·03**	..	..	..	..	..	..	..	
	Average of Brick Beds ..	**7·9**	**12·43**	**4·57**	**7·86**	**2·68**	**2·03**	*Nil*	**·006**	*Nil*	
	Average of Fine Beds ..	**7·8**	**3·96**	**1·85**	**2·11**	**·73**	**·77**	**2·09**	**·19**	*Nil*	

somewhat more dilute than that obtaining in 1906; but it will be observed by comparing the Tables XII (*b*) and XII (*c*), that the difference between the two is in reality extremely small. It would appear that the brick beds were not giving as good purification as in 1906, but the final effluent from the contact beds is very similar.

Looking at the particulars of these analyses, the chief point that strikes one, is that the amount of colloid matter in the final effluent is excessive, and the amount of dissolved oxygen, taken up from a dilution of 1 in 20 is much greater than it should be. We have already pointed out that effluents containing a large amount of organic material in colloid suspension are greedy of dissolved oxygen.

The nitrate figure is fairly satisfactory. The appearance of the effluent is rather milky, and it has a slightly earthy odour.

As a result of the investigations on septic tank latrines, particularly those relating to the characteristics of crude sewage, it was decided that if an installation, similar to Dr. Fowler's, was to be of practical use, it was necessary to give up intimately mixing the excreta and the water, for this would never occur under actual working conditions; consequently our staff were ordered for the future not to make a mixture, but just to place the night-soil in the receiving tank, add the water and give a stir round. By this method the hard masses remained intact, and passed in this form into the coarse beds.

A series of analyses have been carried out, making use of this unmixed sewage, and some very extraordinary results have been obtained. These will be found set forth in Table XII (*d*).

It will be observed that the 4 hours' value of the crude sewage varies considerably; this is always the case with an unmixed sample, the reason being that in the fœcal discharges of 10 individuals, the amount of semi-solid excreta varies from day to day; it is not infrequent to find that the 4 hours' oxygen figure is as low as 7 and may be as high as 17. A comparison between the Tables XII (*c*), XII (*d*) will show that, in the main, the effluent from the fine contact beds is comparatively little altered by this change in the character of the sewage. There is a falling-off in the amount of nitrates, but this is probably due to the fact that a greater percentage of nitrogenous material is retained in the coarse beds. There is a slight improvement in the amount of colloids in the final effluent for the same reason. The ammonia figures are much the same in the 2 tables. But the extraordinary point brought out by Table XII (*d*) is the erratic nature of the 4 hours' oxygen figure obtained from the effluent of the coarse beds. Table XII (*e*) gives a further series of analyses exemplifying the same extraordinary irregularity; in both these tables it will be observed, that, in quite a fair number of samples, the 4 hours' oxygen figure has increased after 4 hours' contact in the brick beds. The explanation of these occurrences is not easy; at first we suspected that during the rest in contact with the bricks, some of the masses in the crude sewage must have been broken down, and having mixed with the sewage, caused an increase in the oxygen absorption power. This, however, may not be a correct explanation, because on inspecting the beds, masses of fœces still remain visible between the bricks, when the fluid part of the sewage has been withdrawn; it may be due to the same cause

as the increase in the 4 hours' oxygen figure in the bottle and grit chamber fœces (*vide* Tables V (*a*) and

TABLE XII (*e*).

Origin.		Chlorine.		4 hours' Oxygen test.	
Crude (unmixed)	..	7·8	7·0	13·71	13·42
No. 2 Brick bed	..	7·8	7.0	10·65	9·04
No. 2 Fine bed	..	8·2	7·0	3·91	3·01
Crude (unmixed)	..	7·8	6·6	11·94	9.59
No. 3 Brick bed	..	7·8	6·6	12·15	14·16
No. 3 Fine bed	..	7·6	6·6	4·30	3·05
Crude (unmixed)	..	8·0	7·6	8·13	13·01
No. 4 Brick bed	..	8·0	7·6	9·31	10·43
No. 4 Fine bed	..	7·8	7·6	2·95	4.21
Crude (unmixed)	..	8·0	5·8	12·31	10·23
No. 5 Brick bed	..	8·0	5·8	12·61	10·93
No. 5 Fine bed	..	7·8	5·8	3·30	4·49
Crude (unmixed)	..	8·0	5·4	14·00	13·26
No. 1 Brick bed	..	7·8	5·4	12·26	12·95
No. 1 Fine bed	..	7·6	5·4	4·80	4·35

IV (*a*)). Whatever is the explanation, it apparently does not affect the purity of the final effluent from the fine contact beds to any very great extent.

From the dimensions of the tanks already given, and from the fact that the fœcal discharges of 10 individuals are placed in each, once in 5 days, it follows that there are 2 users per cubic yard of material per diem. It seems to be very doubtful whether the arrangement of putting the total discharges of 10 individuals into one bed and then leaving it to recover for 5 days, is really sound for the tropics with its high tem-

perature, dry hot winds and rapid drying action. The experience gained on other installations seems to show that it would be very much better, from the point of view of efficiency, to add the excreta of 2 users on 5 consecutive days, diluting it down to a suitable strength, *i.e.*, a 25-gallon sewage.

Again, two users per cube yard of material per diem, has been found by experiments in other contact beds, to be an unnecessarily liberal allowance. So a series of experiments were conducted, steadily increasing the number of users per cube yard, and observing the result in the effluent. In the description of the installation already given, it will be remembered that there are 5 pairs of contact beds, each containing one cubic yard of material, each pair being dosed in turn once in 5 days. In order to increase the number of users per cube yard, it was only necessary to throw out of action 1, 2 or more beds, till eventually one bed was filled daily. The average of the results obtained by this procedure are given in Table XII (*f*), the number of users per cube yard being 2, 6, 8 and 10, according to the number of beds used. Before taking the samples for analyses, the beds were worked for a considerable length of time under the new conditions, to allow them to accommodate themselves to the extra load put on them. Probably better results could have been obtained had still longer time been available before analysing the effluents.

The great point to be observed in these results is, that, considering everything, there is very little deterioration in the quality of the final effluent, whether the beds are disposing of the fœcal discharges of 2, 4 or 10 individuals per diem; there are no marked signs of overwork. It is, of course, true that the amount of nitrates

TABLE XII (d).

FOWLER'S INSTALLATION (SEWAGE UNMIXED).

Date.	Origin.	Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	Nitrogen. Saline and free.	Nitrogen. Albumenoid Ammonia.	Nitrogen. Nitrous and Nitric.	Amount of dissolved Oxygen left. After 24 Hours.	Amount of dissolved Oxygen left. After 48 Hours.	Remarks.
2-5-10	Crude (unmixed) ..	8·0	8·95	..	..	..	..	..	..	..	
2-5-10	No. 5 Brick bed ..	8·2	13·08	2·98	10·10	3·08	1·85	*Nil*	*Nil* (1 in 20)	*Nil*	
2-5-10	No. 5 Fine bed ..	8·0	3·58	1·79	1·79	·80	·82	1·97	·35 (1 in 20)	*Nil*	
3-5-10	Crude (unmixed) ..	7·8	14·60	..	..	..	..	..	..	..	
3-5-10	No. 1 Brick bed ..	8·2	11·73	2·85	8·88	2·14	1·60	*Nil*	*Nil* (1 in 20)	*Nil*	
3-5-10	No. 1 Fine bed ..	8·0	2·75	·82	1·93	·67	·61	2·53	·44 (1 in 20)	·22	
4-5-10	Crude (unmixed) ..	7·8	15·22	..	..	..	..	..	..	..	
4-5-10	No. 2 Brick bed ..	8·4	16·49	5·92	10·57	3·20	2.51	*Nil*	*Nil* (1 in 20)	*Nil*	
4-5-10	No. 2 Fine bed ..	8·0	8.00	4·00	4·00	·64	1·34	1·44	*Nil* (1 in 20)	*Nil*	
5-5-10	Crude (unmixed) ..	7·8	7·51	..	..	..	..	..	..	..	
5-5-10	No. 3 Brick bed ..	7·4	15·02	4·35	10·67	3·46	2·43	*Nil*	*Nil* (1 in 20)	*Nil*	
5-5-10	No. 3 Fine bed ..	7·6	4·14	2·90	1·24	·86	·79	1·85	·32 (1 in 20)	·15 (1 in 20)	
6-5-10	Crude (unmixed) ..	8·6	12·13	..	..	..	..	..	..	..	
6-5-10	No. 4 Brick bed ..	8·4	8·44	3·29	5·15	3·20	1·49	*Nil*	*Nil* (1 in 20)	*Nil*	
6-5-10	No. 4 Fine bed ..	8·4	3·20	1·42	1·78	·83	·64	1·88	·53 (1 in 20)	·33 (1 in 20)	
Average of Crude (unmixed) ..		**8·0**	**11·68**	..	..	..	..	..	..	..	
Average of Brick beds F 1's ..		**8·1**	**12·95**	**3·87**	**9·07**	**3·01**	**1·97**	*Nil*	*Nil*	*Nil*	
Average of Fine beds F 2's ..		**8·0**	**4·33**	**2·18**	**2·14**	**·79**	**·84**	**1·93**	**·32**	**·14**	

in the effluent appears to fall off steadily in proportion to the increase in the work put on the beds. The individual analyses, from which the averages are prepared, show, that the longer the time that had elapsed since the last increase in load, the greater the amount of nitrates. So in all probability, if any pair of beds had been fed with the excreta of 10 individuals, for a period of 6 months, the nitrate figures would show a great increase on those given in the averages quoted in Table XII (*f*). It will be observed that 10 users per cube yard is almost identical with the allowance made by Mr. Dibdin in the Gouripur installation, quoted in the previous chapter.

From a very careful scrutiny of a large number of analyses it is not possible to state that the grading of the material in any one bed (A_1, A_2, or A_3, etc.) has given better purification than that of any other of the series.

The results obtained from the fine contact beds in this installation are, in respect to the ammonia figures, superior to those from Gouripur (*vide* last chapter). This is due to the better quality, and the finer crushing of the material in Dr. Fowler's beds.

Another important comparison is the difference in the results obtained between the brick beds in Fowler's installation and the slate beds in Gouripur. In the case of Fowler's installation 4 hours' rest in the brick beds had usually been allowed. As long as the sewage *was carefully mixed*, the amount of purification which takes place in the coarse beds is very considerable. But with an unmixed sewage such as would be obtained in working installations, the results appear to be very erratic and difficult to understand. On the whole, the figures show that the coarse or brick beds in Fowler's installation have never given such good

results as have been obtained, under certain conditions, in the Gouripur installation. They have never disposed of anything like the same amount of colloid material as the slate beds have done. The reason is that probably the slate beds are distinctly superior to beds made of bricks or drain pipes. As in the Gouripur results, fine contact beds *alone* do not appear to be able to remove more than a certain amount of material in colloidal suspension, the major portion must be removed in the brick or slate beds if a good effluent is to be obtained. We have recently fitted up for experimental purposes, one of the tanks in Fowler's installation, with slates exactly on the line laid down by Mr. Dibdin. Unfortunately, the bed is not yet sufficiently ripe to quote any of the results.

With beds whose capacity is only about 50 gallons, it is not possible to give any accurate figures as to the loss in fluid capacity from the deposit of sludge, but inspection shows that the lower layers of the beds are practically solid, so that the reduction must be considerable.

Total nitrogen estimations of the sludge obtained from the 5 brick beds have been made. They, however, show a very great irregularity in the amount of nitrogen present. The figures are given below. No explanation of the results can be given, although the sludges were taken under exactly similar circumstances following on a 5 days' rest.

Total Nitrogen from Sludge of Coarse Beds.

Bed No. 1	..	1·38 % of dried sludge.
Bed No. 2	..	2·60 % „ „
Bed No. 3	..	4·99 % „ „
Bed No. 4	..	4·20 % „ „
Bed No. 5	..	1·89 % „ „

The following conclusions can reasonably be drawn from the results obtained with Fowler's installation. It must, however, be remembered that the installation was not intended for practical use in its present shape. It was primarily constructed for research work. Therefore, it is not fair to lay particular stress on any practical defects:—

(1) That nitrification of an oriental sewage can be satisfactorily brought about by aerobic means only.

(2) Considerably better final results could have been obtained had the material in the brick beds been of better quality.

(3) That even with the disadvantage mentioned above, a fairly satisfactory effluent has been obtained with 10 users per cube yard of material.

(4) That working with a five-gallon sewage no difference in efficiency could be detected between any of the five brick or fine beds, although considerable differences were present in the material used.

(5) It would appear that very much better purification is obtained in the brick beds with a thoroughly well mixed than with an unmixed sewage.

CHAPTER XIII.

ADVANTAGES AND DISADVANTAGES OF PRELIMINARY ANAEROBIC TREATMENT OF SEWAGE.

IN the last two chapters purely aerobic installations have been described and the results discussed. It is now necessary to see how this type of disposal arrangement compares with the model in which the anaerobic or septic tank forms an integral part. At this time septic tanks appear to be in disfavour with many sewage experts in Europe, and aerobic beds (without preliminary septic treatment) are coming into vogue. It is therefore desirable to see whether the merits and demerits of these different systems are the same in the East as in the West, for it will doubtless be conceded that the working conditions are radically different. In the following comparison it should be understood that an installation, in every way resembling that at Gouripur (consisting of collecting tanks, slate beds and fine contact beds) will be taken as the type of the aerobic method, and the septic tank latrine with a streaming filter will be considered the standard of the anaerobic combined system. The subject divides itself into three heads—

The difference between the two types of installations from (I) chemical, (II) engineering and (III) utilitarian or general sanitary point of view.

I.—The Chemical Aspect.

In order to discuss the question as to which of these types of disposal arrangements is chemically the most suitable to tropical conditions, it will be necessary to say a few words on the objections, of a chemical nature, usually put forward to the septic tank. From the results given in Chapters IV, V and VI, in which the study of the effluents obtained from both model and working septic tank installations is given, it will be apparent that more satisfactory results are obtained from anaerobic tanks in this country than have been reported in Europe. The important reason for this state of affairs appears to be, that, the sewage we were required to treat in India is derived from a population, who are almost entirely vegetarians, whereas in Europe it contains the excreta of a meat-eating community. This is the fundamental difference between the sewage of these two parts of the globe. The following paragraphs will demonstrate the practical importance of this difference.

Dunbar, in his work on "The Principles of Sewage Treatment," gives the following objections to the septic tank as used in Europe :—

(*a*) "*The tank effluents are always putrescent and give rise to foul smells by the escape of gases when they are agitated. The most important of these gases, Sulphuretted Hydrogen, may possibly be fixed before leaving a tank.*"

The truth of this statement is generally accepted as applying to septic tanks in the West, though it is not by any means necessary to carry the septic action so far as the production of H_2 S. The vegetarian sewage of the East does not produce H_2 S readily ; the tanks when they are agitated do *not* give off evil smelling vapours. There is no denying that some of the best septic tank effluents do possess a certain amount of odour, but

it is not fœcal in nature, nor is it mainly due to the presence of Sulphuretted Hydrogen. In natural surroundings decomposing animal matter, whether it be in the shape of rotten eggs, meat, or such like substances, readily produces Sulphuretted Hydrogen, but decomposing vegetable matter, though not free from evil odour, does not produce H_2 S, and this gas is not the chief cause of any nuisance that may be noticed. Quoting again from Dunbar's work, he says—"*It is the sulphur and not the nitrogen which is the cause of the nuisance arising from the decomposition of nitrogenous organic matter: it is the sulphur which forms the foul smelling of Sulphuretted Hydrogen and which is strongly poisonous to fish-life. The ammonia derived from the organic nitrogen can scarcely be smelt in putrifying sewage.*"

This is undoubtedly true. But as H_2 S is not readily formed in vegetarian sewage, nuisance is not of frequent occurrence. Chemical analyses of a vegetarian and meat-eating sewage show distinctly that the amount of organic sulphur present in the former is much less than in the latter, *vide* Chapter VII. But this is not all. It would appear from the results obtained from the septic tanks in this country, that the sulphur is linked up in the vegetable proteid molecules in such a way, that it does not readily form compounds with hydrogen. We do not say that H_2 S is *never* formed, but the process is slow and the amount negligible. The whole of the research work in Chapter VI is evidence in favour of the truth of this statement. The best effluent derived from these model septic tanks was obtained with a rest in the tank equal to three days. Making due allowance for the strength of the sewage, such a result would be impossible in Europe, on account of the

development of H_2 S in the effluent. Another strong point in confirmation of the statement is, that the incubator test is practically useless when dealing with a vegetarian sewage. A very indifferent effluent can be kept in the incubator for a week without developing any H S; consequently the test is not a good indication of putrescibility.

The importance of this great difference between the sewage in the East and West cannot be over-estimated. There is, no doubt, whatever, that things are possible in this country, which would be completely out of the question in dealing with a European sewage. For instance, would any Engineer or Sewage Specialist consider it wise to keep the solid fœcal material from a sewage shut up in a small chamber for weeks or probably months until such time as it becomes fluid? But this device is not only possible with an Oriental sewage, but is strongly to be recommended. The research work on grit chamber fœces (Chapter IV) demonstrates the fact, that 50% of the organic nitrogen can be disposed of during the leisurely process of breaking up the solid masses and yet no bad smell or H_2 S is formed. The development of H_2 S lies at the root of all the complaints against septic tank in the West; as this has not occurred in the East, when dealing with a vegetarian sewage, the foundation of these objections is cut away.

(*b*) "*The biological treatment is usually more difficult with septic tank effluent than with fresh sewage.*"

"*At Hamburg contact beds could be filled six times a day with fresh sewage without yielding an unsatisfactory effluent, whereas they would only take septic sewage twice a day.*"

These two quotations from Dunbar's work may not be entirely accepted as true by all authorities in Europe.

For the same author goes on to say—"*The contrary opinions of English authors may be ascribed to the fact that they have compared fresh sewage, containing the whole of its suspended matter, with septic tank effluent containing very little suspended matter. Under such circumstances it is only to be expected that filters will clog up sooner with fresh sewage than with a septicised sewage. At Leeds, as soon as a settled sewage was used, the results obtained were the same as those at Hamburg.*"

We do not pretend to be able to discuss this question from the point of view of a European sewage, but it is safe to say (1) that in the East it is impossible to get a sedimentation without a septic action on account of the high temperature, many putrefactive actions going on with extraordinary rapidity, and (2) most of the suspended matter in a vegetarian sewage is colloidal in nature and this cannot be removed by rapid settlement. Experiments in this country seem to show that there is practically no difference between the ease with which both a septicised and non-septicised sewage can be nitrified. Table XIII (*a*) gives the results of various methods of treating sewage in this country, and it will be observed that the results obtained with both septicised and non-septicised sewage are very similar in all cases. A comparison should be made between the results of the Gouripur and Fowler's installation on the one hand, and those obtained from the model and working septic tanks on the other.

If a thoroughly mixed, dilute, fresh, tropical sewage were subjected to both kinds of treatment side by side, it is just possible that a greater quantity per diem per cubic yard of material, of this raw sewage could be nitrified, than would be the case if it were subjected to preliminary septic action. But, in the first place, no such

TABLE XII (*f*).

FOWLER'S INSTALLATION WITH INCREASING LOAD.

ORIGIN.	CHLORINE.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid organic.	NITROGEN.			AMOUNT OF DISSOLVED OXYGEN LEFT.		REMARKS.
					Saline and free.	Albumenoid Ammonia.	Nitrous and Nitric.	After 24 Hours.	After 48 Hours.	
2 Users per cube yard—										
Average of Crude (unmixed) ..	8·0	11·68	...	...	...	...	...	...	...	
Average of Brick beds ..	8·1	12·95	3·87	9·07	3·01	1·97	*Nil*	*Nil*	*Nil*	
Average of Fine beds ..	8·0	4·33	2·18	2·14	·76	·84	1·93	·32	·14	
6 Users per cube yard—										
Average of Crude (unmixed) ..	...	11·24	...	...	...	...	...	...	...	
Average of Brick beds ..	6·2	10·89	3·15	7·41	2·90	2·12	*Nil*	*Nil*	*Nil*	
Average of Fine beds ..	7·0	3·64	1·88	1·75	·71	·83	·77	·45	*Nil*	
8 Users per cube yard—										
Average of Crude (unmixed) ..	...	9·64	...	...	...	...	...	...	...	
Average of Brick beds ..	6·9	12·44	3·14	9·30	2·14	1·97	*Nil*	*Nil*	*Nil*	
Average of Fine beds ..	...	4·16	1·89	2·27	1·06	·65	·66	·40	*Nil*	
10 Users per cube yard—										
Average of Crude (unmixed) ..	...	13·28	...	...	...	...	...	...	...	
Average of Brick beds ..	7·2	10·14	3·49	6·65	4·51	1·41	*Nil*	*Nil*	*Nil*	
Average of Fine beds ..	...	3·39	1·81	1.51	1·07	·67	53	·36	*Nil*	

thing, as a dilute, thoroughly mixed sewage is, under ordinary conditions, obtainable in this country; and secondly, the amount of colloid material is so great, that a good result cannot be expected with very rapid action. We have seen in the results obtained from Fowler's installation, that even scientifically designed, fine contact beds will not remove more than a certain percentage of colloid material when worked very lightly.

Another very interesting series of experiments have been carried out by making use of what we call the Nitrification test. The results are given in Table XIII (*b*). In this case a large number of different effluents, derived from working and model septic tanks, from the brick beds in Fowler's installation and slate-beds in Gouripur, were collected on the same day. A sufficient quantity of water was added to each sample to bring the 4 hours' oxygen figure of the mixture to 3 parts per 100,000; to each an additional half litre of tap water was added and each was placed in a Winchester quart bottle. Every day this mixture was well shaken up and tested for the presence of nitrites. The results obtained by this experiment are extremely interesting. In series No. 1 the crude sewage took 13 days before any nitrites were observed. The first to develop nitrites were two effluents derived from slate-beds at Gouripur. This occurred on the 5th day. On the 6th day, however, the effluent derived from a working tank at Shamnagar and from tank No. 1 (3 days' rest) of our models also developed nitrites.

In the second series the action seemed to have been rather slower, but in this case almost similar results were obtained, namely, that our model tank No. 1, the Clive Mill tank, and two effluents from the slate-beds at

TABLE XIII (b).

NITRIFICATION TESTS.

Series I.			Series II.		
I.	Entally Crude ..	13 days	I.	Entally Crude ..	24 days
II.	Fowler Installation Bed I ..	12 days	II.	Fowler Installation Bed I ..	17 days
III.	Do. Bed II ..	9 days	III.	Do. Bed II ..	13 days
IV.	Model Septic Tank I ..	6 days	IV.	Model Septic Tank I ..	9 days
V.	Do. II ..	8 days	V.	Do. II ..	12 days
VI.	Do. III ..	9 days	VI.	Do. III ..	13 days
VII.	Do. IV ..	10 days	VII.	Do. IV ..	13 days
VIII.	Gouripur Slate-Bed I ..	6 days	VIII.	Gouripur Slate-Bed 2 hrs. contact ..	11 days
IX.	Do. II ..	9 days	IX.	Do. 3 hrs. contact ..	10 days
X.	Do. III ..	5 days	X.	Do. 4 hrs. contact ..	9 days
XI.	Do. IV ..	7 days	XI.	Do. 5 hrs. contact ..	9 days
XII.	Do. V ..	5 days	XII.	Do. 6 hrs. contact ..	10 days
XIII.	Shamnagar Tank I (unfiltered)	10 days	XIII.	Septic Tank, Clive Mill ..	9 days
XIV.	Do. Tank II (unfiltered)	6 days			
XV.	Do. Tank III (unfiltered)	7 days			

Gouripur, all developed nitrites simultaneously. Consequently, it would appear, that there is practically no difference between the ease with which a good septic tank effluent, or an effluent derived from an aerobic bed can be nitrified, under the circumstances described above. It is not maintained that this experiment is free from all fallacies, but the results are distinctly striking; further these figures and those given in Table VI (*l*) are sufficiently similar to show that no very serious objection can be raised to their accuracy. Hence, we are inclined to think that all our experiments show that a thoroughly septicised sewage derived from a vegetarian population is as easily nitrified as a similar sewage treated only on aerobic beds.

(*c*) "*The Sulphuretted Hydrogen formed in the tanks attacks the cement.*" We have already shown that little or no Sulphuretted Hydrogen is ever formed in the tanks. Therefore, this objection has no weight in the East. Our tanks in this country do leak or "sweat" when they are new, but as a general rule, the pores of the masonry fill up within the first six months and no further trouble is experienced.

These are the main chemical objections to the septic tank. The advantages of septic tanks have been referred to in the earlier chapters of this work, but they may be briefly recapitulated—

(1) The solids in true suspension, whether mineral or organic, settle out of the sewage.

(2) Colloid material is disposed of to a large extent. A large proportion is turned to crystalloids, but some undergo a process of sedimentation.

(3) Diminution in the organic part of the sludge takes place in the tank due to digestion. Dr. Fowler puts the figure at 50%, but the subject has not yet been thoroughly worked out.

(4) The sludge from the septic tank is light and easy to remove and is absolutely inodorous.

(5) Crude sewage is prepared for nitrification and a large number of highly complex and often evil smelling bodies are mineralised and changed into inodorous substances.

(6) The hard masses of fœces, that occur in fresh sewage, undergo chemical decomposition and are eventually made into an emulsion with the water.

(7) Large quantities of inflammable gas are given off and may, under favourable conditions, be used for lighting or developing power.

Hence it will be apparent that the chemical objections to septic tanks in the East are not of any serious importance, whilst the changes brought about in the crude sewage are all in the right direction from the Sanitarian's point of view.

II.—The Engineering Aspect.

The amount of fall required by the two kinds of installations.

One of the most important limitations of these aerobic installations in a flat country like Bengal, and most places on the plains of India, is that they require a very large amount of fall; considerably more is necessary than is required for a septic tank and streaming filter. The latrine in an aerobic installation would have to be raised very high or the sewage must be pumped into the collecting tank. The Gouripur installations consume no less than 14 feet of fall, not taking into account the tank for chlorinating the effluent. The collecting tank is 4ft. deep and the two contact beds 5 each. Of course, this amount was actually available at this Mill; it is not

maintained that with less than 14ft. it is impossible to design a similar installation. It would, however, be difficult to do this with less than 10ft.; even if very shallow beds were constructed (such as 2ft. for the collecting tank and 3 each for each contact bed, giving a total of 8ft.) the cost would be greatly increased. A septic latrine and streaming filter can be easily and economically constructed without any loss of fall at all. This is obtained by building the tank above ground, as is shown in the diagrams attached to Chapters II and III, so that in reality the sewage is given a head of 6ft. by the coolies having to go up the steps into the latrine.

Cost of the Two Types.

The cost of an aerobic installation is at all times greater than that of a septic tank and streaming filter. Even with plenty of fall available, the amount of masonry required for the collecting tank and tanks for the double contact beds, is very much in excess of that required for a single septic tank and filter. As we have already stated in the foregoing paragraph, within certain limits the less fall there is available, the more the installation will cost.

Loss of working capacity in the Aerobic installation.

The subject of the rapid sludging up of the slate-beds has been discussed at length, and nothing further need be said; it is however apparent, that, with a fresh sewage, containing large masses of fœcal material, the rate of decrease in the fluid capacity of the slate-beds is so great as to practically render the whole plant useless. In a septic tank installation we have no such objection. It is very easy to design a tank from which

sludge can be removed periodically without any difficulty or nuisance. Tanks that have been in work for a period of six or seven years, satisfactorily disposing of a 5 or 6-gallons sewage, have been found to contain only about 12 inches of a light, easily removable sludge.

Difficulty in obtaining Slates.

Slates can only be obtained with great difficulty in this country. It is better to import them from Wales, though this is an expensive business, even for places that are situated on a river and near a large port. The expense would be doubled or quadrupled if railway freight were added to the cost of transit by sea. The slates that are available in this country are bad in quality and extremely difficult to obtain.

III.—Utilitarian and General Sanitary Aspect.

Difficulty of Working Aerobic Beds.

Aerobic installations possess all the working disadvantages that have already been enumerated when discussing contact beds. There is no necessity to repeat them. The impossibility of getting contact beds worked regularly has been sufficiently emphasized. It would be difficult to describe the consequences of a strike amongst the sweepers attending to an aerobic installation, such as the one at Gouripur. But a septic tank latrine with a streaming filter might be left entirely to itself for a week or a fortnight, without causing any inconvenience or nuisance to anybody.

Dunbar says that "*The accumulation of putrifying substances should on general sanitary grounds be prevented*

as much as possible. This is specially the case in the neighbourhood of dwelling houses." This is given as an objection to the septic tank. As a matter of fact, the septic tank in this country is very much less likely to give rise to nuisance than the aerobic installation. In a properly designed latrine, there should be little or no smell and the tank itself gives off no bad odour. In aerobic installations, worked with an unmixed sewage, the filling of slate-beds gives rise to nuisance. Under certain conditions of the atmosphere in India, slate-beds standing full of sewage undoubtedly create a bad smell. Again open slate-beds are accessible to flies ; this is a serious matter in the East. From considerable experiences we venture to state that a septic tank and continuous filter gives rise to less nuisance than an aerobic installation.

Conclusion.

From the above points it may be concluded, that, from a chemical point of view, the anaerobic and aerobic installations are equally efficient. That the objections to the aerobic installations under the head of difficulty of working, causation of nuisance and engineering considerations are extremely strong. The advantages in the shape of simplicity in working, the avoidance of nuisance, cheapness and freedom from serious disturbing influences are all on the side of the septic tank and filter.

CHAPTER XIV.

THE "DUMPING" SEPTIC TANK.

THE second most important application of the Biological system to Tropical conditions is what, for want of a better term, has been called the "Dumping" Septic Tank. The primary object of this arrangement is to dispose of night-soil that has been collected by the conservancy staff and conveyed, either by hand or in carts, to the disposal depôt; in other words, it is intended to be a substitute for the "trenching ground." A rough idea of the night-soil removal arrangement, which obtains in nearly every small town in India, has already been given in Chapter I. It must be remembered that private and public latrines are served by sweepers who remove the night-soil in either buckets, hand-carts, or in bullock-carts to a plot of ground where it is trenched. The chief objections to the trenching ground itself are: (1) that the trenching ground is seldom properly managed; (2) in many places it is under water during the monsoon months; and (3) sometimes the only land suitable for trenching is miles away from the town from which the night-soil comes. It is therefore perfectly obvious, that, provided water can be had in sufficient quantity, a septic tank and filters would be both more sanitary and more economical than many existing trenching grounds. The parts of the country where this method of disposal of night-soil could with

advantage be started are Lower Bengal and much of Eastern Bengal and Assam; here water is plentiful and land suitable in character for trenching purposes is extremely hard to find, as it is usually submerged during the rains. Some towns on the Malabar Coast also labour under great disadvantages in their attempts to dispose of night-soil, partly on account of the heavy rainfall, and partly from the difficulty of obtaining a suitable trenching ground.

The disposal of night-soil in "dumping" tanks should be borne in mind in all places where large irrigation canals exist; the necessary water-supply may be taken from these, and as a general rule the raiyats in the neighbourhood of the tank will be extremely pleased to receive the effluent on their land, on account of its manurial value; failing this, land should be acquired and a sewage farm started. It is impossible to discuss all circumstances under which a dumping tank would cause an improvement; the above are the most important. We are inclined to believe that Sanitary Officers throughout India would be extremely pleased to be rid of trenching grounds, with their many faults and objections, and to substitute a more sanitary and scientific method of disposal of night-soil whenever the conditions are favourable.

Position of Tank.

The position in which a "dumping" septic tank should be constructed will usually be governed by many considerations, such as proximity to water-supply, nearness to the place where the effluent has to be finally disposed of, etc., so that there probably will not be any very large amount of choice in the site. The following

principles should however be carefully borne in mind :—

Dumping tanks should *not be placed in a town* or in very close proximity to it ; the reasons for this is not because the tank and filters will give rise to nuisance but because it is physically impossible to " dump " night-soil from carts or from buckets, without a certain amount of nuisance. A great deal can be done to mitigate this by bringing the night-soil to the "dumping" tank in comparatively small quantities, as is the case when buckets and hand-carts are in use. These give rise to less nuisance, both on the road and in the process of emptying, than larger carts drawn by bullocks, simply on account of the smaller mass of material they carry. It is also better not to have "dumping" tanks situated on the side of the town from which the prevailing wind comes.

If the tank is to be placed on the banks of a river and the effluent passed into it, the installation should obviously be situated below and not above the town.

Wherever the tank is located, a good pucca road should be constructed, for ease in conveying the night-soil to the tank.

Dilution of the Sewage.

It is necessary to dilute the mass of crude excreta with a suitable amount of water. Experience has shewn that it is not desirable to manufacture a sewage which is too strong when "dumping" tanks are used. For, as much of the night-soil is not fresh, and a certain amount of breaking down action will occur during transit, the chances of obtaining a large proportion of hard masses are considerably reduced.

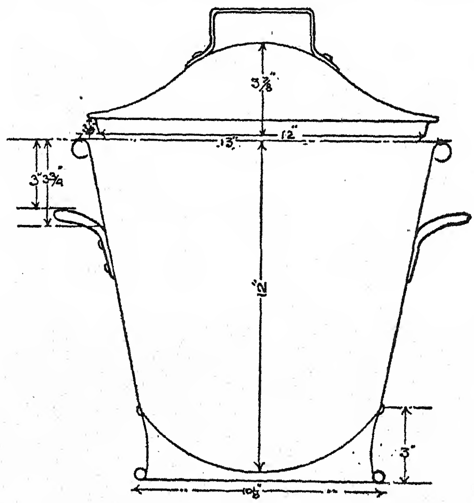
The strength of the mixture will therefore approximate much nearer to the figure obtained at Entally, when the excreta was thoroughly mixed with water, so the grit chamber action will not be a large factor in the purification of this sewage. Hence for "dumping" tanks we consider that 8 or even 10 gallons per user will probably give the best result. We do not recommend that the purification of anything as strong as 5 gallons be attempted in this variety of tank. There is no doubt whatever, that it would be possible to get quite a respectable effluent with this strength of sewage, provided always that care was taken in making the dilution; but considering that we do away with the slow purifying action in the grit chamber, it is distinctly advisable to err on the side of making a sewage too weak rather than too concentrated.

Design of the Tank.

(*a*) *The Dumping Depôt.*

The first step in designing a satisfactory dumping and diluting plant, is to take a preliminary survey of the conditions under which the night-soil is conveyed to the disposal depôt, for in no two places are these identical. The first thing to ascertain is whether any urine or only night-soil is brought; in many places, where the private latrines are extremely primitive, the urine either soaks into the ground or flows down open drains. Another point which must be decided is, whether the night-soil is carried in buckets, hand-carts or by bullock-carts. We strongly recommend all the night-soil be brought in buckets of standard pattern; it then becomes a simple matter to make a satisfactory dilution. Each sweeper who serves

a certain number of private latrines should be provided with a bucket of known capacity and standard size; each bucket should be provided with a tight fitting lid; they should not be too large, otherwise when full the sweepers, whether male or female, will not be able to carry the weight. The accompanying sketch shows a very suitable pattern. It was designed by Dr. Seal of Darjeeling, and is satisfactory, but it is rather too large.



With buckets of standard size it is obviously easy to estimate how much water it is necessary to add per bucket of night-soil, in order to get a correct dilution, in terms of gallons per individual. If the buckets are of different sizes, or if the night-soil is carried in bullock carts, this matter becomes more complex. The usual difficulty in the way of using buckets *entirely* is, that, sometimes

night-soil has to be carried from a part of the town some miles distant; in that case it is necessary to employ bullock-carts. When this is the case, separate dumping

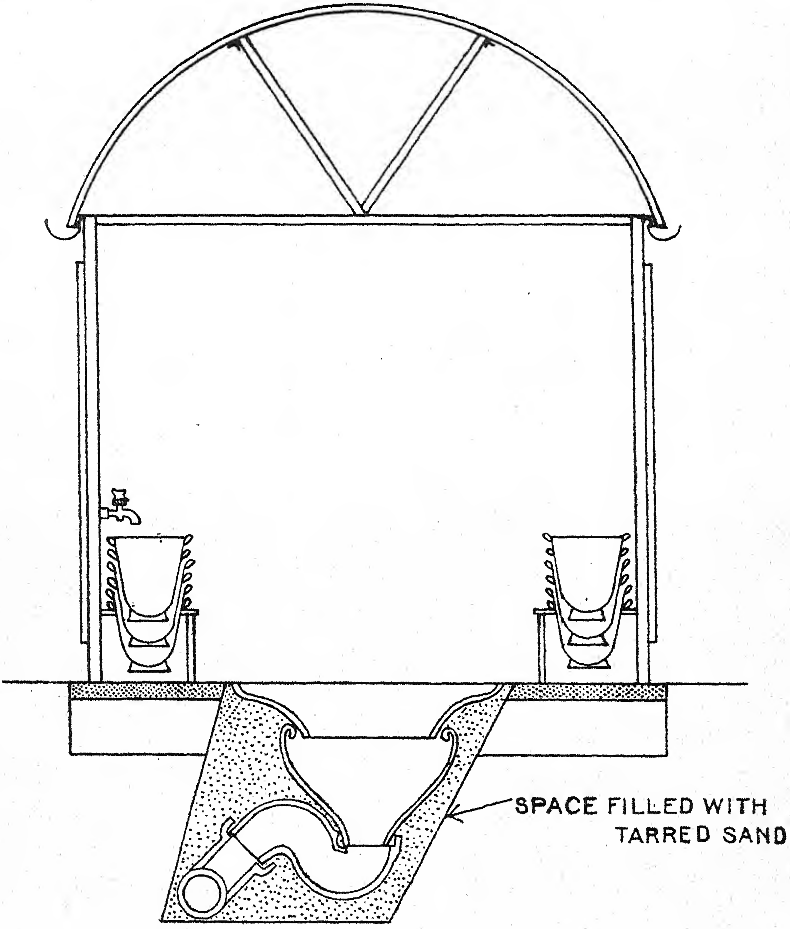


FIG. XIV (*a*).—Dumping Depôt for night-soil brought in Buckets. The Trap is unnecessary; designed by G. Robertson, Esq.

arrangement for buckets and carts must be constructed. Of course, this double system considerably increases the cost of the installation; wherever possible one system, and one only, should be made use of. Hand-carts possess practically all the advantages of buckets, without the disadvantages of bullock carts.

One gallon of night-soil represents the fœcal discharges of 12 individuals, provided that no urine is present; the consequence is that an ordinary bucket of 5-gallons capacity, represents the excreta of about 45 individuals when $\frac{3}{4}$ full, the condition in which it most frequently arrives at the tank. For a 10-gallon dilution the flushing arrangements will be required to discharge 450 gallons per bucket.

The best arrangement for getting night-soil into the tank is a funnel-shaped pan not unlike a large water closet in design, *vide* Figure XIV (*a*). On the whole, it is advisable *not* to have a syphon trap, because this very much delays the passage of the night-soil into the tank. The most important point in the design of this dumping pan is that the pipe, leading into the septic tank itself, *must be large;* under no consideration should it be less than 6 inches in diameter, because it is not by any means easy to get a bucket of night-soil, through a smaller orifice than this, even with a good flush of water. It can, of course, be done, but the process is a slow one; *the rapidity with which the night-soil is consigned to the tank is the important factor in determining whether nuisance is created or not.* We have seen what might have been a very satisfactory sewage removal scheme completely spoilt by the fact that the dumping arrangements were too small, consequently, the nuisance was very great.

The Fig. XIV (*a*) gives a plan of a satisfactory "dumping" depôt; it does not require any very elaborate description. If this installation is situated outside the town in a remote place, there is no necessity to have side walls to the dumping depôt, but if, as is sometimes necessary, it is placed on a sewer in close proximity to houses, it is better to close the place in, and have a long ventilation shaft.

In each dumping depôt an adequate water-supply for washing of buckets must always be provided, the wash water flowing into the dumping pit and passing into the sewer. In some installations a grating is used in the dumping pan in order to retain such things as sticks, rags and bricks, which are occasionally brought along with the night-soil in the buckets. The arrangement is sound, but it very materially delays the passage of the night-soil into the tank. The mesh of the grating should be very coarse so as only to retain large objects and to impede the passage of the night-soil as little as possible.

There are several methods of adding the requisite amount of water. In some cases we have seen a syphon flush, actuated by hand, as in a water closet, has been fitted. We do not recommend this because it gets out of order. By far the best arrangement is to provide a large tap over the dumping pan and to attach about two feet of hose to this, so that the whole of the pan can be washed down easily.

A careful estimate of the quantity of water discharged per hour from the tap should be made, and also an estimate of the number of buckets of night-soil dumped; it then becomes a simple calculation to ascertain for how many hours per diem the tap should be allowed to run.

Thus, if the night-soil from a population of 1,500 people is to be dumped daily, to make an 8-gallon dilution 12,000 gallons of water will be required. If the tap discharges 3,000 gallons per hour, it will obviously take 4 hours to add the requisite amount of water; thus it is only necessary to tell the sweeper in charge to open the tap when dumping commences at 7 A.M. and stop it at 11 A.M. If a more complicated system is made use of, it will not be properly carried out.

(*b*) *Design of the Tanks.*

The design of the tanks varies very little from what we have already described in the septic tank latrine. The shape, the depth, the position of sludge cocks and man-holes are in every way the same. The arrangement of the grit chamber does not require any alteration. With a 10-gallon sewage the rest in the tank should be 36 hours; there is no object in having it longer than this. If, however, water is scanty and only 8 gallons per user is available, then proportionately longer time in the tank should be allowed, that is to say, for an 8-gallon sewage 48 hours is adequate, and for a 5-gallons a full 3 days' rest should be arranged for in calculating tank capacity. It will be found that dumping tanks receiving a very small quantity of urine often give poor results, particularly when new; the presence of urine seems to assist somewhat in the septic action.

For a dumping tank where the amount of sewage may vary very considerably in quantity at different times of the year, as for instance would be the case in a school tank during holiday time, it is advisable to have the available tank capacity either in a pair or in 3 or 4

similar tanks. This does not increase the cost very greatly and it gives very much greater elasticity of working; thus in the instance given, one out of 3 or 4 septic tanks might be sufficient for the number of users in the institution during the recess; the disused tanks may be emptied or be fed with a certain amount of water daily.

The usual practice is to roof septic tanks with masonry arches leaving large inspection doors where necessary. The roof is not always advisable, specially if the conditions under which the tanks are going to be used are not very well known. A cover of wood with earth, on which grass is growing, forms a cheap and convenient roof and it is easily opened up if required.

A very important practical point in designing a dumping tank is that the inlet part must be covered up with an air-tight covering; experience has shown that it is the inlet end of the tank that gives rise to nuisance, the crude sewage, whether arriving in pipes or carts, being invariably very offensive; consequently the covers of the inlet chambers should always be very tight and adequate ventilation, by means of shafts, should be provided. On the score of economy the tank, whenever levels will permit, should be sunk in the ground; if this is done, then one of two methods must be adopted for the removal of sludge, either that given in Fig. III (*c*) where sludge pipes are fixed into the tank, a pump being used to remove the sludge, or a drain must be provided along the outside of the tanks leading into some low-lying ground, so that the sludge may be removed by simply opening the cocks. The drain may also be utilised as a subsoil water drain in the event of the subsoil water being very high.

(*c*) *Filters.*

Whether aerobic filters are necessary or not must depend on the circumstances of each installation. Presuming that it is desirable to nitrify the effluent, exactly the same design of filters as those laid down for the septic tank latrines, are necessary in this case also. If fall is available, filters may be placed at some distance from the tank on a lower level and jet distributers may be used. If the available fall is very little, then it is recommended that a battery of small, controlled, heap filters be arranged, the effluent being distributed either by troughs or some other simple appliances. Contact beds may also be used if there is any special indication for putting them in.

The great point about all these installations and the primary difficulty in designing them is to avoid, or at any rate to reduce as much as possible, the nuisance that is caused by dumping crude night-soil into the tank; if this is overcome by satisfactory design and by careful working, there is no doubt whatever that the tank itself will carry out its functions satisfactorily without any nuisance.

The advantage of this method of disposal of night-soil over the ordinary trenching grounds may be briefly summarised as follows :—

(1) The method is sanitary.

(2) The installation can be worked equally well in dry as well as in wet weather and is not upset by floods.

(3) The whole of the sanitary imperfections of trenching grounds, such as filling the trenches too full of night-soil, breeding of flies and many others disappear.

(4) On the whole, this method is cheap in the long run. The tank can be placed close to a large town as long as it is not in close proximity to houses and near much frequented roads. This will often enable a considerable

reduction in the staff of cartmen, bullocks, etc. The amount of nuisance caused by a properly designed dumping tank is very much less than that from a badly run trenching ground. The effluent from it has considerable manurial value. As a general rule it is easier to dispose of a septic tank effluent to cultivators than to get them to take night-soil. This, however, does not apply to all parts of India, for in many of the southern districts, as Madura and Malabar, night-soil finds a ready market for rice cultivation.

The disadvantages are principally those inherent to all Biological processes, *viz.*, the necessity for ample water and a place to dispose of the effluent.

The initial cost is another point that must be mentioned, though in several places known to us, the saving effected by reduction of staff would pay for the tank in 5 years.

If special pumping plant is necessary to supply the water, the working charges are increased, and little saving can be expected.

Of course, it must be understood that a dumping tank cannot be left entirely to itself; flushing arrangements and all mechanisms must be of the simplest and strongest. Under any circumstances a little careful supervision is necessary.

CHAPTER XV.

THE USE OF SEPTIC TANKS IN SMALL DRAINAGE SCHEMES.

IN the first chapter of this work it was pointed out that septic tanks might be of great value in improving the sanitary condition of small hamlets or wards of towns, when combined with a very simple water-carriage system for the removal of night-soil. It is hardly necessary to repeat that India has not yet arrived at a stage when closets and house connections can be installed as a usual practice. The cost of doing so would be prohibitive, and the people are not sufficiently educated to require these arrangements. There is, however, no reason why a much cheaper scheme, possessing most of the good points of the water-removal system, without the expense of water closets, should not be installed, thereby doing away with many of the most glaring faults of the hand-removal system. An idea of what is meant will be best understood by giving a series of examples.

The sanitation of hill stations is always a troublesome problem, the satisfactory trenching of night-soil being almost an impossibility. The difficulties of the hand-removal system are, as compared with plain stations, multiplied five or six fold.

Darjeeling is the chief hill station in Bengal, and as regards its sanitary imperfections, is no exception to the ordinary rule. Recently a scheme has been drawn up

COMPARATIVE RESULTS OF VARIOUS METHODS OF TREATMENT.

	Origin.	Strength of Sewage.	Number of Users per cube yard of filtering material.	Analysis of Resulting Effluent.									Remarks.
				Chlorine.	4 Hours' Oxygen value.	4 Hours' Oxygen value after clarification.	Colloid Organic.	Nitrogen.			Amount of Dissolved Oxy. Left.		
								Saline and free.	Albumenoid Ammonia.	Nitric and Nitrous.	After 24 hours.	After 48 hours.	
Septic Tank and Filtration Bed.	Lower Hughli Filter ..	6 gals.	5	*89·0	1·63	1·43	·20	1·47	·57	1·73	·47	·35	Effluent from a fairly good tank and moderately designed filter.
	Fowler's Filter ..	?	27(?)	5	1·16	·90	·26	·43	·055	2·73	..	..	Effluent from a tank used mostly as a urinal and a very well arranged small filter.
	Model Contact Bed I, with bad Septic tank effluent	5 gals.	3	7·2	3·76	3·26	·50	1·73	·71	1·47	·55	·52	Corresponds to indifferent Tank Effluent with single contact.
	Do. with good septic tank effluent ..	5 gals. (unmixed)	3	6·8	1·47	1·32	·15	1·10	·22	1·00	·55	·43	Corresponds to good septic tank with grit chamber plus one contact.
	Do. two fillings with good effluent ..	5 gals.	6	7·2	1·68	1·30	·38	1·42	·37	·62	·41	·18	
	Model Contact Bed II, with bad septic tank effluent	5 gals.	3	7·2	2·47	2·13	·34	·44	·51	3·68	·58	·55	Corresponds to indifferent Tank Effluent with double contact.
	Do. with good septic tank effluent ..	5 gals. (unmixed)	3	6·8	·92	·83	·09	·48	·14	2·15	·58	·45	Corresponds to good septic tank with grit chamber and double contact.
	Do. two fillings with good effluent ..	5 gals. (unmixed)	6	7·4	·97	·97	*Nil*	·58	·18	2·25	·59	·57	
Purely Aerobic.	Fowler's installation as designed	5 gals.	2	7·8	3·6	2·0	1·6	·50	·77	2·25	·37	·10	
	Filled every 3rd day ..	do.	6	7·0	3·64	1·88	1·75	·71	·83	·77	·45	*Nil*	Better results could have been obtained if the increase in work had been more gradual.
	Do. 2nd day ..	do.	8	6·9	4·16	1·89	2·27	1·06	·65	·66	·40	*Nil*	
	Filled daily	do.	10	7·2	3·39	1·81	1·52	1·07	·67	·53	·36	*Nil*	
	Gouripur Installation ..	6-7 gals. 12 gals.	10-12 10-12	7·7 4·2	2·11 ·8	1·47 ·76	·64 ·04	3·95 1·20	·42 ·25	2·35 ·84	·53 ·53	·37 ·48	

* Sea water present in the river water.

for laying what we call 'skeleton sewers' and connected latrines. The Fig. XV (*a*) gives a good example of the sort of scheme that is being constructed. The plan XV (*a*) is known as the Bhutia bustee section. This bustee is a small hamlet situated outside of Darjeeling proper. The houses are perched on small terraces on the hill-sides; they are in many cases too close together, as the plan shows; there is nothing of the nature of a street in the locality. Many of the house-owners possess small private latrines, usually of a bad type; others use the public latrines. The population of the hamlet is about 2,500 souls. Removal of night-soil from both public and private latrines is difficult, as the bustee is situated at least 6 miles from the trenching ground of Darjeeling, and 3½ miles from the depôt where night-soil is loaded in the train. The difficulty of removing the night-soil not to mention the urine, of 2,500 people across the steep slopes of a spur of the Himalayas can be imagined. It was, therefore, decided to put in a few hundred yards of cast-iron pipes, to convert the public latrines from a hand-removal to a water-removal type, and to arrange for "dumping depôts" in public latrines, so that the matter from private latrines would only require to be conveyed by hand a few hundred yards. At the end of this short length of pipe a small installation of septic tanks and aerobic filters was placed. In this system there are six connected latrines. The water for the system is, as a temporary measure, specially pumped by an electric pump from a mountain stream somewhat below the tanks. A reference to the plan will show the general outlines of the scheme, so that further description would be unnecessary. The improvement effected by a small scheme of this kind is extremely great. In the first place, the night-soil is now properly disposed of,

instead of being scattered all over the hill-side, and a reduction in the number of sweepers for this bustee is possible. The cost of installation including the pump and motor is about Rs. 18,000, but with a cheaper type of latrine the cost could have been reduced.

Fig. XV (*b*) gives three other systems on very much the same lines, that are shortly to be installed in Darjeeling. Blocks A and B are in the main bazaars of Darjeeling. It is very overcrowded like most hill bazaars and satisfactory removal of night-soil by the hand-removal system is extremely difficult. It will be observed that comparatively short lengths of pipes, to which all public latrines and dumping stations are connected, will effect an enormous improvement in the sanitation of the town. The simplicity of the system is its chief good point.

It may be argued that the sewage in a place like Darjeeling might be discharged down the hill-side without any treatment whatever. This is hardly to be recommended; the cost of septic tanks and filters adds very little, if anything, to the cost of the scheme, for they can be constructed for nearly the same sum as would be expended on the purchase of pipes to carry the sewage a greater distance below the town.

A few instances of the application of the same system to plain stations may also be quoted. Fig. XV (*c*) gives a drawing of the railway shops at Jamalpur. The place covers about 40 acres of land and employs 12,000 hands. In this case a modification of a sewage system combined with septic tanks has been installed and is giving very satisfactory results. The design of the latrine is given in Fig. III (*a*), (*b*), (*c*). In this case septic tank latrines are placed in convenient situations for the workmen at various points of the yard. A, B, C, D, etc.,

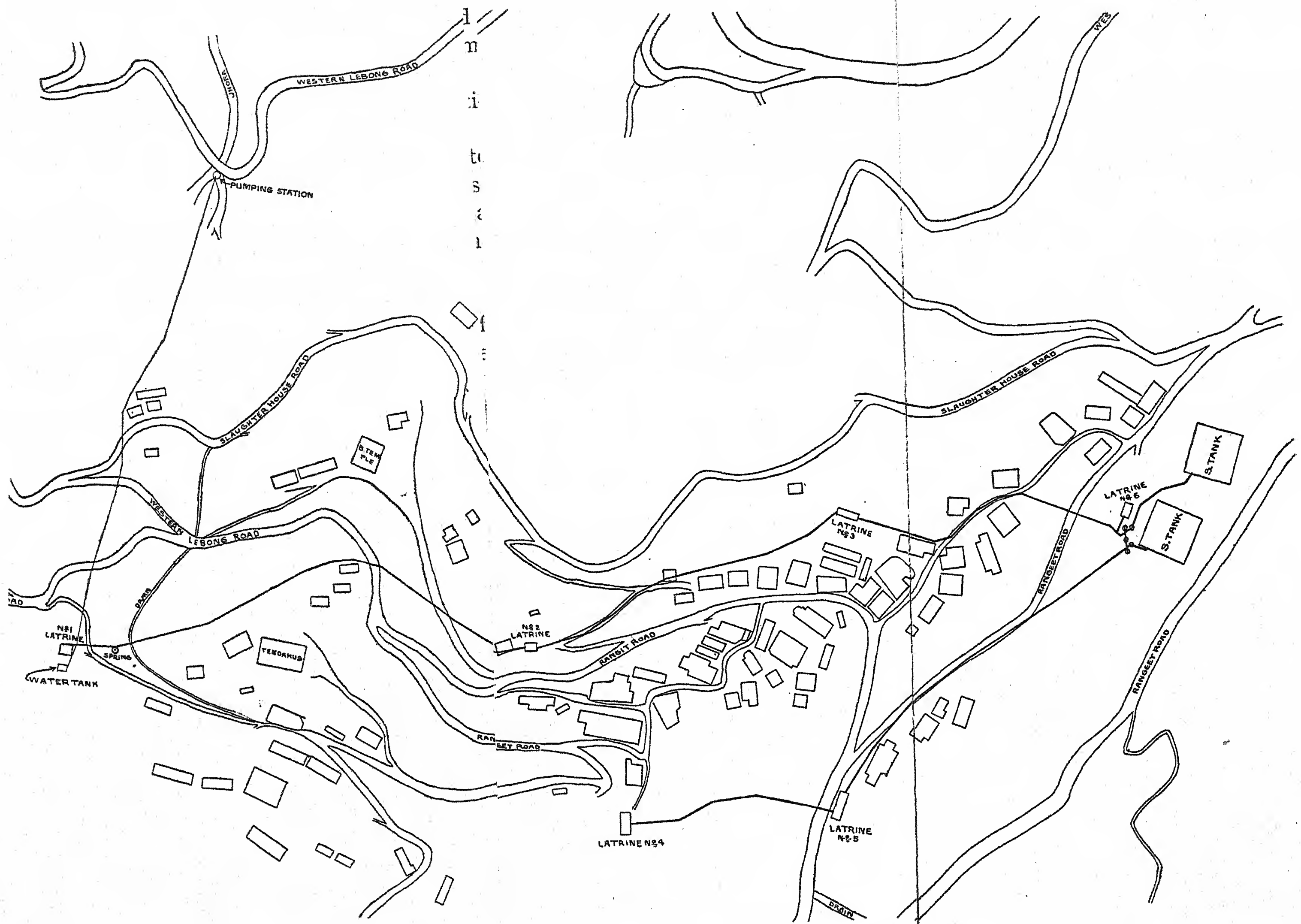
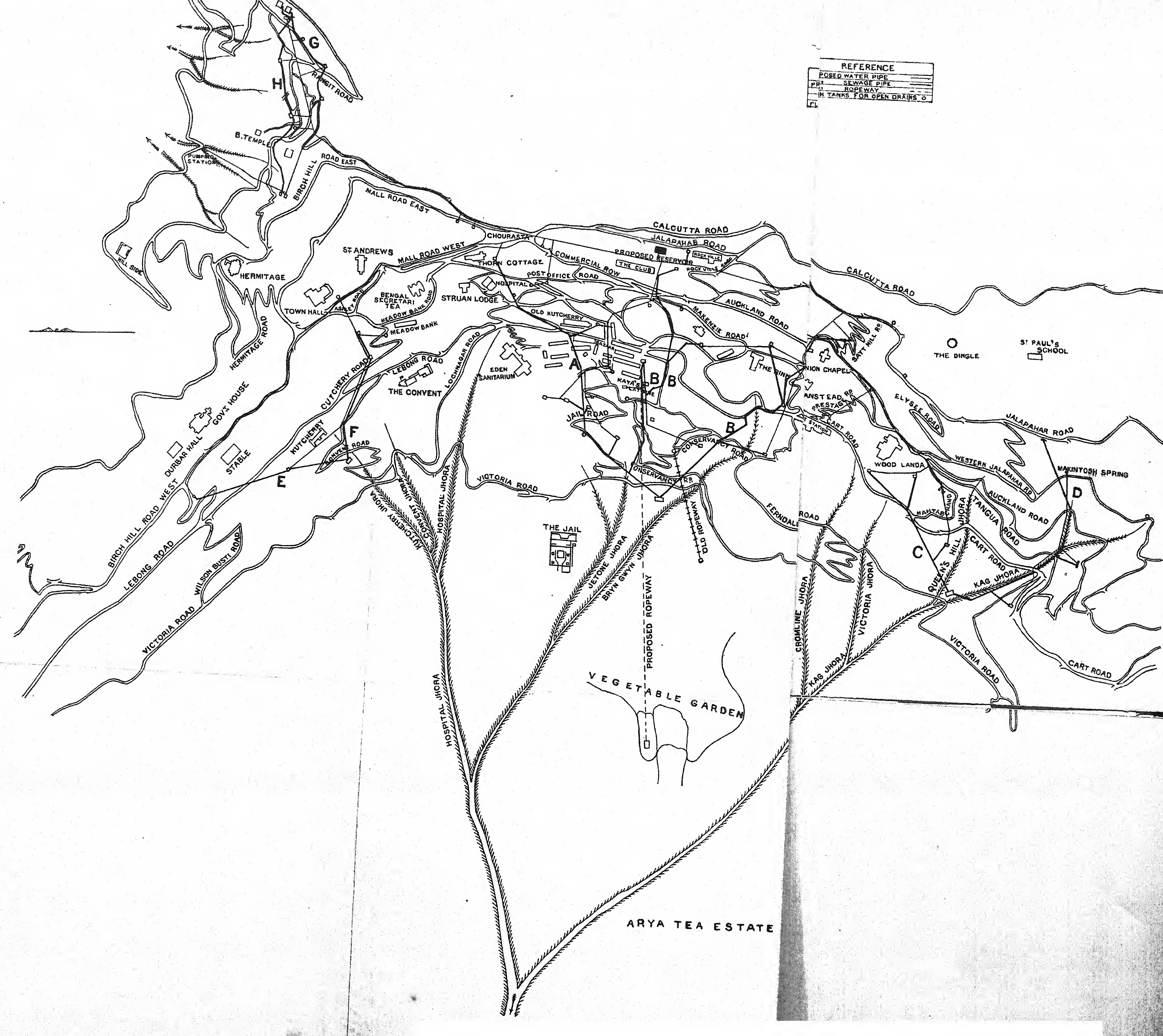


FIG. XV (a).—Bhutia Bustie Section of Darjeeling Scheme. Iron sewers are shown in black lines.



REFERENCE
POSED WATER PIPE
SEWAGE PIPE
ROPEWAY
TANKS FOR OPEN DRAINS
CALCUTTA ROAD
JALAPAHAR ROAD
PROPOSED RESERVOIR
THE CLUB
ROCK VILLE
CHOURASTA
MALL ROAD EAST
MALL ROAD WEST
BIRCH HILL ROAD EAST
RANGIT ROAD
B. TEMPLE
PUMPING STATION
HILL SIDE
HERMITAGE
HERMITAGE ROAD
ST. ANDREWS
TOWN HALL
ASHLEY ROAD
BENGAL SECRETARIAT
MEADOW BANK ROAD
MEADOW BANK
THORN COTTAGE
COMMERCIAL ROW
POST OFFICE ROAD
HOSPITAL
STRUAN LODGE
OLD KUTCHERRY
BAZAAR
AUCKLAND ROAD
MAKENZIE ROAD
THE RINK
UNION CHAPEL
SATT HILL RD.
THE DINGLE
ST. PAUL'S SCHOOL
ELYSEE ROAD
JALAPAHAR ROAD
WESTERN JALAPAHAR RD.
MAKINTOSH SPRING
ANSTEAD RD.
PRESTAGE RD.
CART ROAD
STATION
WOOD LANDA
AUCKLAND ROAD
TANGUA ROAD
MAHTAB CHAND
QUEEN'S HILL
JHORA
KAG JHORA
CART ROAD
VICTORIA ROAD
CROMLINE JHORA
VICTORIA JHORA
FERNDALE ROAD
CONSERVANCY ROAD
OBSERVATORY RD.
OLD ROPEWAY
PROPOSED ROPEWAY
BRYN GWYN JHORA
JETONE JHORA
THE JAIL
JAIL ROAD
KAYA'S CATTLE SHED
EDEN SANITARIUM
LOCHNAGAR ROAD
LEBONG ROAD
THE CONVENT
CUTCHERY ROAD
KUTCHERRY
CONVENT ROAD
STABLE
DURBAR HALL
GOVT. HOUSE
BIRCH HILL ROAD WEST
LEBONG ROAD
WILSON BUSTI ROAD
VICTORIA ROAD
KUTCHERRY JHORA
CONVENT JHORA
HOSPITAL JHORA
HOSPITAL JHORA
VEGETABLE GARDEN
ARYA TEA ESTATE
A
B
C
D
E
F
G
H

represent the latrines in the plan. The effluent from these latrines is carried by an underground drain to a plot of ground, where it is put through percolating filters and is finally irrigated over land. It may be argued that this arrangement possesses no advantages over simply installing water closets and laying sewers. As a matter of fact, there are considerable advantages in combining the septic tank and latrine together and placing the filters well away from the workshops in a spot where plenty of space is available. A septic tank effluent can be carried down a much cheaper system of underground drains than crude sewage. The septic tank latrine is in reality very little more expensive than the latrine without the septic tank would be. In this instance the tanks are partially underground, so that this further reduces the cost of construction.

Probably the most satisfactory and elaborate scheme of this type is the one in Malabar Hill in Bombay. Fig. XV (*d*) gives a plan of the whole system. In this case 281 houses of the better class (with a total population of 3,211 souls) are connected by means of underground drains with septic tanks. The kitchen waste water is also passed down the same drains. The effluent runs into the sea. Without the use of septic tanks, it would be impossible to dispose of the crude sewage of this community by passing it into the sea at this point. The scheme is more elaborate than is possible or advisable for ordinary bazaar work, but it is a good example of these minor schemes, in which a septic tank plays an important part.

Other instances could be given of this type of installation, but these will suffice. The point that one wishes to emphasize in giving these examples is, that, *one* difficulty in the way of installing the water-carriage

system has always been, that no suitable place for the disposal of the sewage could be found without making the whole neighbourhood insanitary. The proper use of septic tanks does away with this important objection. It is possible to convert the sewage into a clear, non-putrescible and non-odorous effluent, which can safely be treated over land or, if it is sterilised, pass into a stream.

The place where we consider that this system of sewage disposal arrangements might be extensively used, is in the barracks of British regiments. In all cantonments where there is an abundant water-supply, there is now no reason why water closets and water-fitted urinals should not be established. The improvement in the sanitation of barracks and the consequent improvement in the health of the occupants will amply repay for the expense of these appliances. The result of such a change in Malta has already been mentioned ; one might safely prophesy that a considerable improvement in the general health of British troops in this country would result from the installation of a water-carriage system, and the doing away with the pernicious hand-removal arrangement.

G. XV (*d*).—Drainage Scheme of Malabar Hill, Bombay.

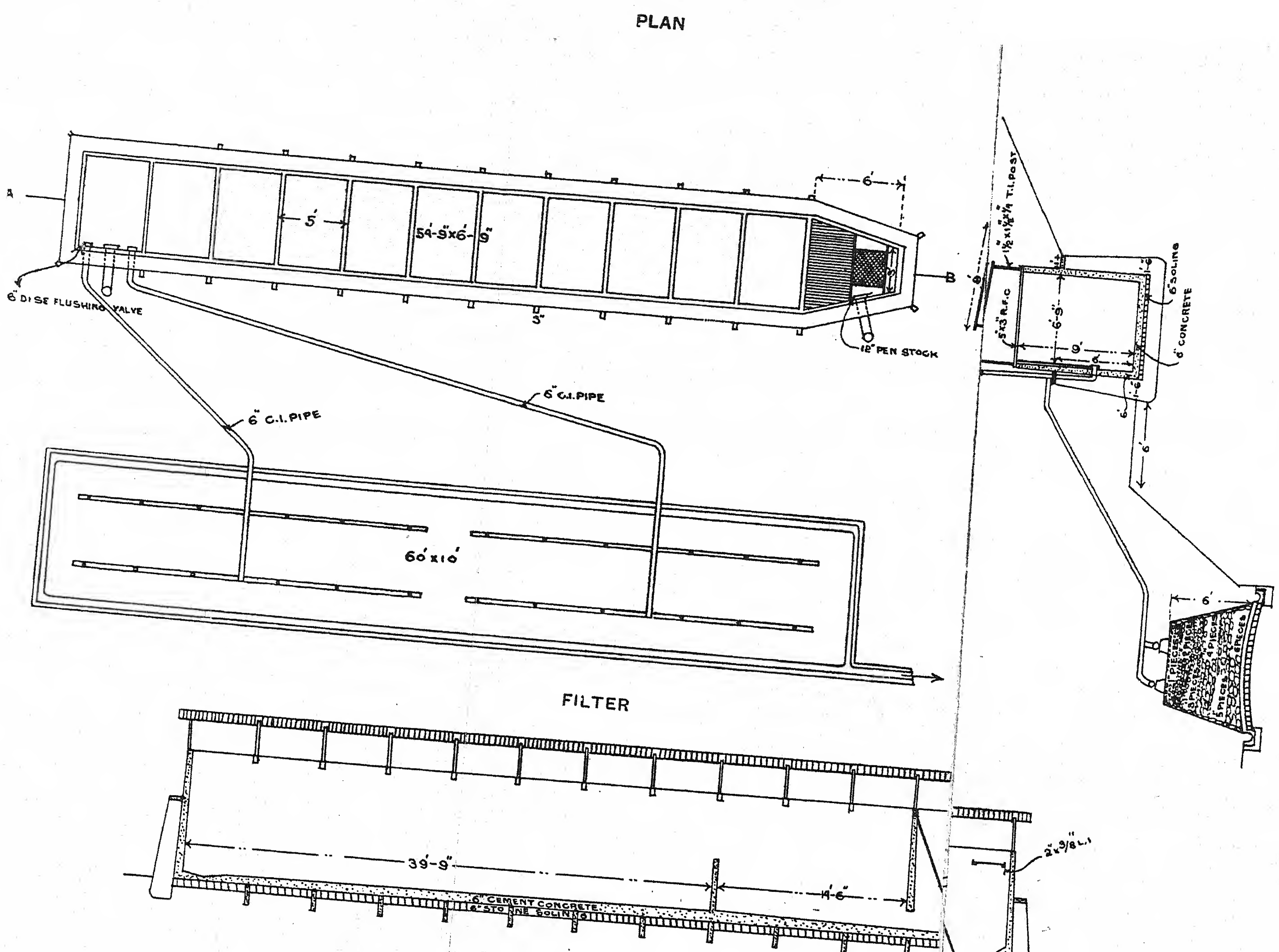


FIG. XV (e).—Section of Bhutia Bustie Tank.
It is made of reinforced concrete throughout designed by G. Robertson, Esq., Municipal Engineer, Darjeeling.

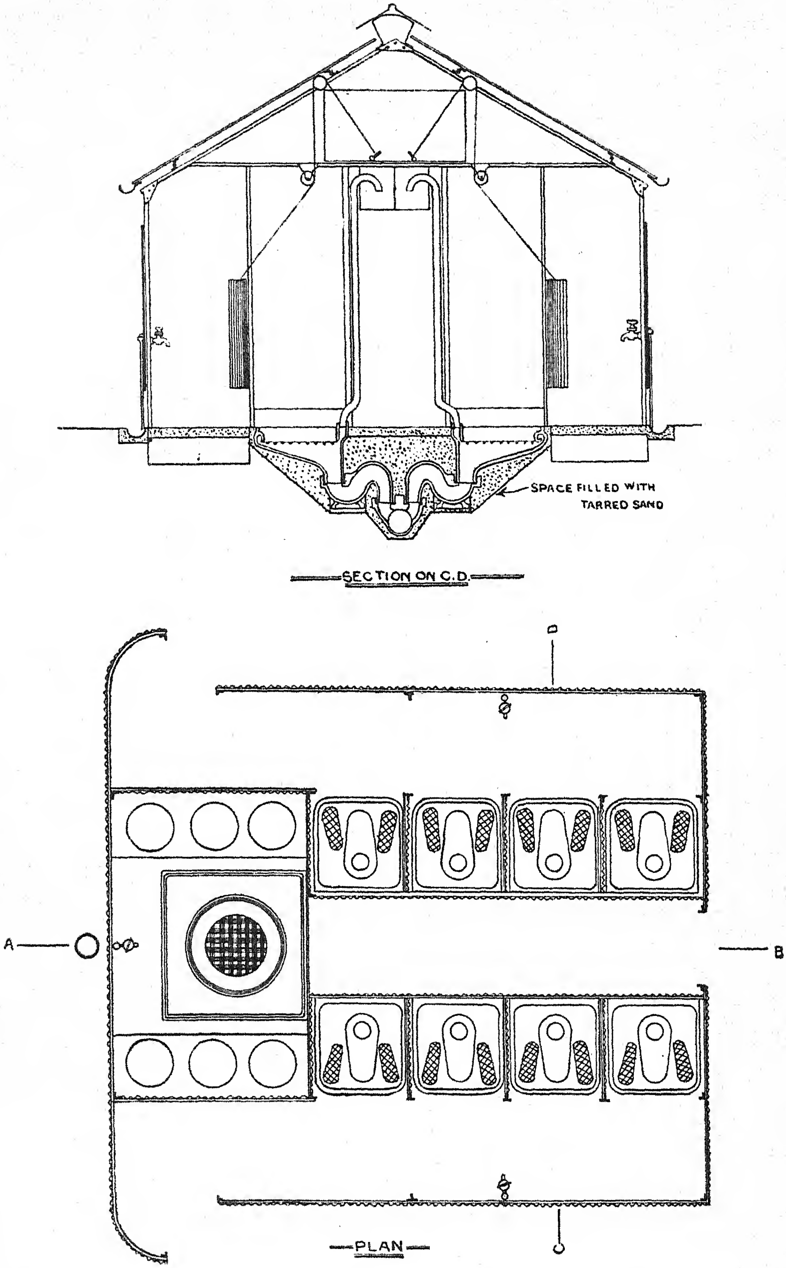


FIG. XV (*g*).—Plan and Section of a very good but very costly type of latrine with dumping depôt attached. The door flushes are not satisfactory. Tw Automatic Syphons would be better.

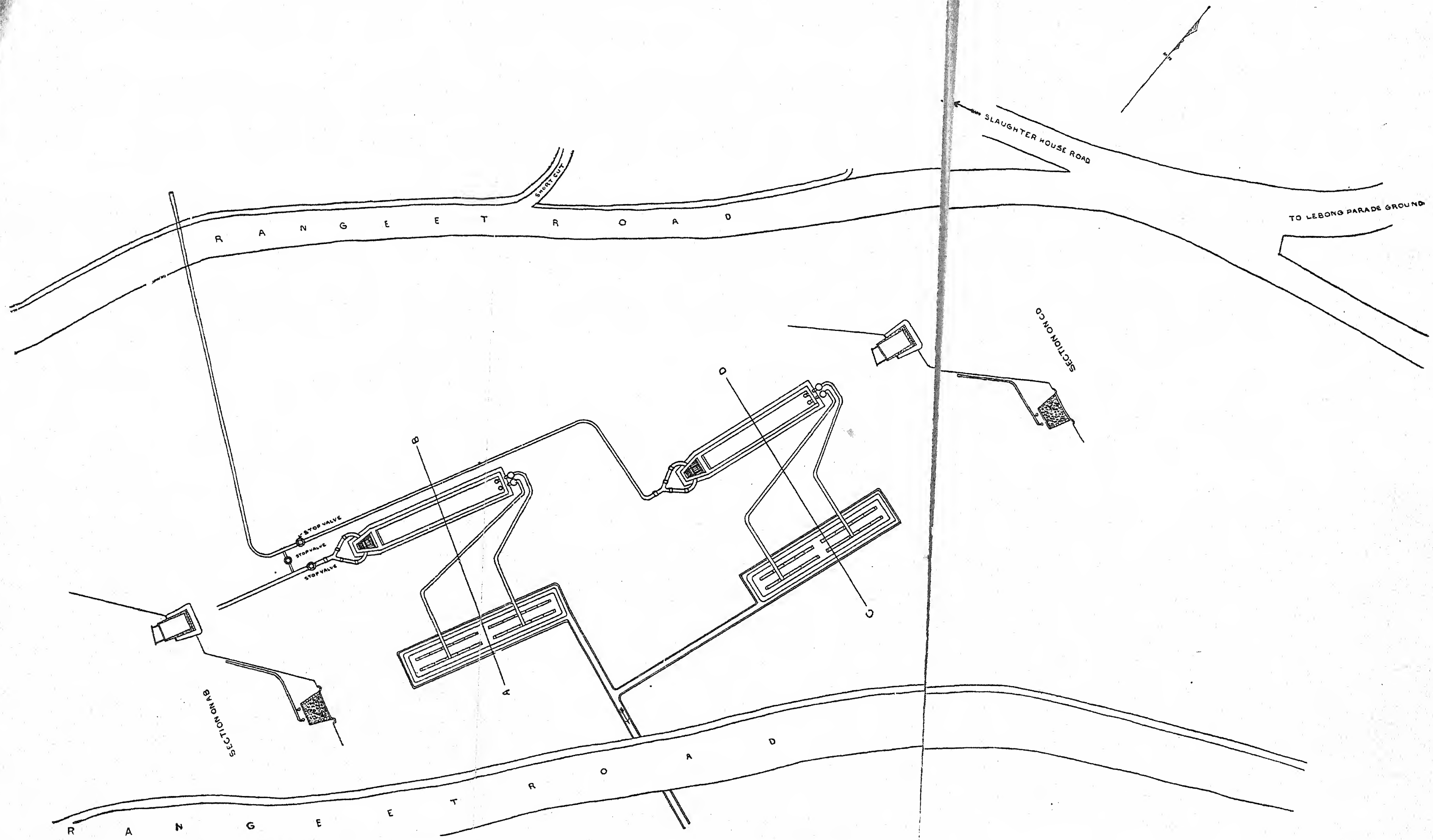


FIG. XV (*f*).—Enlarged plan of Bhutia Bustie Installation.

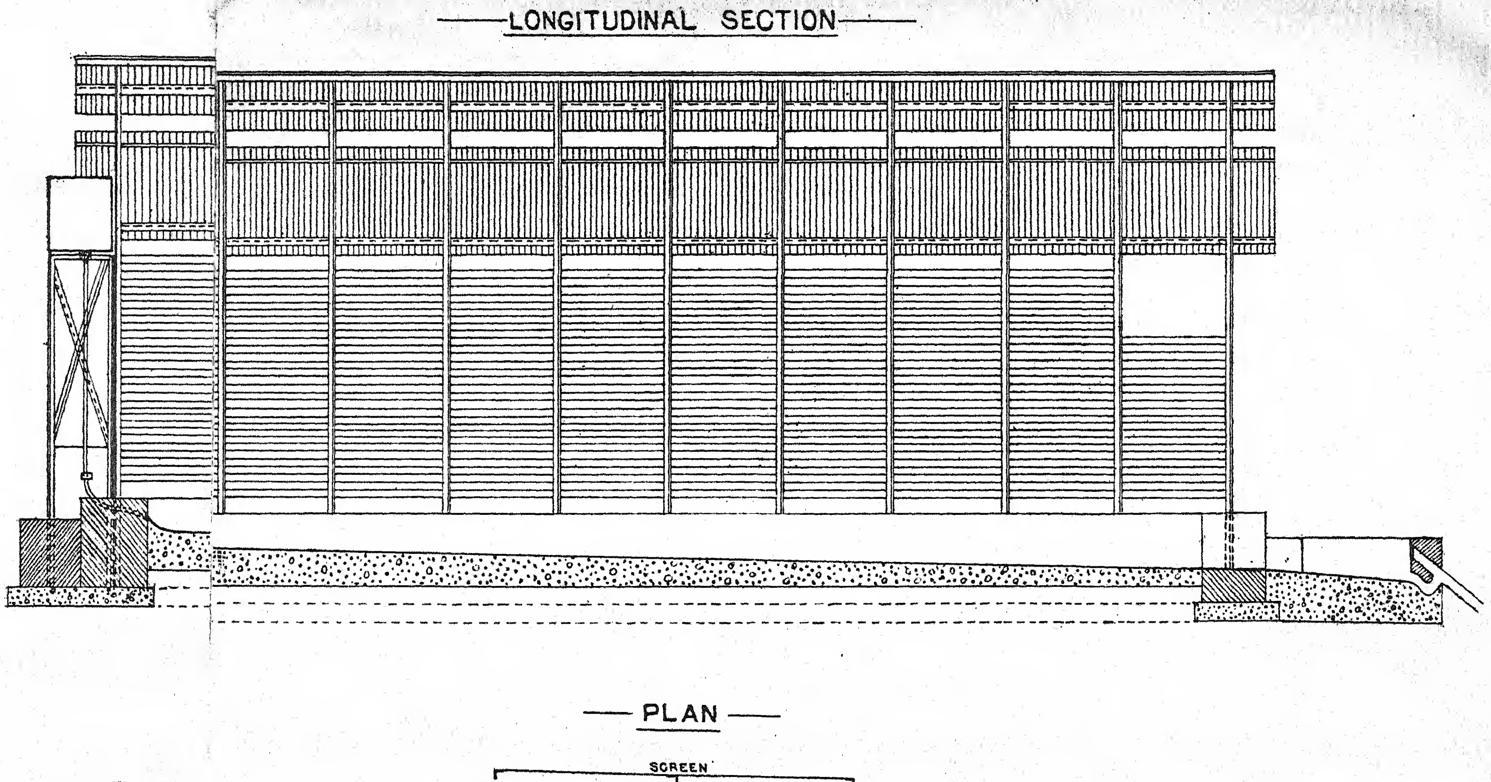


FIG. XV (h).—Plans and Sections of a cheap and efficient type of "connected" latrine. The shape of the trough is capable of improvement, but the latrine is otherwise a good one.

CHAPTER XVI.

THE FINAL DISPOSAL OF SEPTIC TANK EFFLUENT.

IT is extremely difficult for those unacquainted with the conditions of every-day life in the East to understand the great difference between sanitary problems in the two parts of the world; this subject, *viz.*, the ultimate disposal of the septic tank effluent, is a case in point. In Western countries, where practically every town and village has a pipe supply, the possibilities of septic tank effluent being a source of danger to the public, by contaminating a drinking water, are somewhat remote; but in India things are different. It must be understood that there is a certain percentage of the population in this country, who, when they are thirsty, will drink practically any water they come across. Furthermore, very few people, who have not been in the East, will really understand what it means to be short of water for drinking and household purposes. Under conditions such as these, the people have recourse to all manner of sources for their daily supply, small and shallow puddles, streams with a mere trickle of water in them, and many sources, which they themselves recognise as being unsatisfactory. Consequently to pollute a tank, river or stream in the East must always be looked upon as undesirable, for it is extremely likely to affect public well-being. Of course, the people themselves are

extremely careless about the pollution of water; bathing, washing of clothes, not to mention other still more objectionable practices, are very common in village tanks, from which the people draw their daily supply.

Septic tank effluent must always be looked upon as potentially dangerous. Houston's conclusion, that "the effluents from bacteria beds ought to be regarded as hardly, if at all, more safe in their possible relation to disease than the raw sewage before treatment" (*Clowes and Houston*), has been accepted by sanitarians generally, and nobody has, up to the present, challenged the statement. Therefore one cannot look with equanimity on the passing of a quantity of septic tank effluent, however good in quality, into a river from which a large proportion of the population of a town draw their drinking water.

Furthermore, as a general rule, the arrangements for the discharge of septic tank effluent leave very much to be desired; the fluid is usually run down open drains and passed into the river *at the edge*. It not infrequently happens, that just below the outfall there may be a bathing ghât, or places from which drinking water is taken. From chemical and bacteriological analysis of the River Hooghly, there is no doubt whatever that a very inferior quality of water is obtained at the edge; it is not unusual to find some hundreds of intestinal organisms per c. c. in samples taken close to the bank, whereas in mid-stream, only one or two per c. c. are usually present in dry weather. Therefore, if a septic tank effluent has to be discharged into a river, where the volume of water is great, it is better to discharge it well into the stream, so that dilution takes place at once; this is unfortunately impracticable in the Hooghly.

It must not, however, be supposed that fœcal organisms are derived only from effluent ; an inspection of the bank in the morning shows very clearly that the foreshore is used as a latrine by the very people who rely on the river for a drinking supply.

The ordinary methods of the people in drawing their daily supply renders this pollution along the banks doubly dangerous. The housewife goes down to the river, bathes herself, washes some clothes belonging to some member of the household, then having filled her water-pot, takes it to her house for the needs of the family. With this simple and primitive arrangement the possibilities of carrying away a contaminated water seems to be extremely great. It is difficult to imagine what the results would be supposing the rivers in England were used in the same manner. We need not elaborate the point further ; we simply wish to emphasize the statement, that pollution of any water in the East is more dangerous than in the West, because one never knows whether it is used for drinking purposes by some section of the community.

We will now discuss the various methods of disposal of septic tank effluent.

(1) By passing it over land.

This is probably the most satisfactory of all methods of disposal of septic tank effluent. If plenty of land is available, there is no necessity whatever to instal aerobic filters, so that, the whole of the initial cost and maintenance of filters is dispensed with. The reasons for the proviso " as long as plenty of land is available " is, that an unfiltered effluent contains more colloid material than a filtered effluent, therefore the land must not

be overworked or clogging will result. In some parts of India, where this method of disposal is carried out, there is no necessity to underdrain the land, the water passing into the subsoil; in other places drains are advisable.

Another distinct advantage of this method is that with careful management a very considerable profit can be made from the crops produced on the ground; European vegetables, "heriali" grass, oats, potatoes can be grown very satisfactorily on sewage farms. In Ootacamund all these were tried with considerable success; probably the best crop for that part is oats, cut whilst green, and used as fodder for cattle and horses; "Lucerne" and "heriali" grass have also been found to be satisfactory from every point of view. Since the septic tank was installed in Ootacamund, the nuisance, which was occasionally complained of when crude sewage was irrigated, has entirely disappeared.

The limitations of this method of disposal of septic tank effluent are obvious, namely, that it is useless to attempt it unless a suitable soil is available. As a rule, such can be found in all laterite districts, so that in the Madras Presidency this method of disposal of effluent may be looked as the standard. In Bengal and in many other parts of India there is practically no suitable soil. An attempt to irrigate with effluent the clayey alluvia of Bengal would simply result in manufacturing thousands of small puddles, which would, in a very short time, breed millions of mosquitoes. Occasionally patches of suitable soil are found on the banks of the Ganges, where a sandy loam is met with, but this is comparatively rare. In places where septic tanks are likely to be most required, namely, near manufacturing towns, large plots of suitable ground are not easy to obtain.

It will be found that passing effluent over land is usually best suited to a "dumping" septic tank or to tanks which are placed at the end of a sewage scheme, whether large or small, because these are situated outside the town where land is obtainable. In most instances land treatment will not be possible in the neighbourhood of the latrine. The unnitrified effluent may, as is the case in Jamalpur, be run down drains to a plot of ground where it is passed through aerobic filters and irrigated.

We must admit that the scientific aspect of land treatment of effluent in the tropics has not yet received the attention it deserves, partly because we have no opportunity in Bengal of studying the question from working installations. We are therefore not in a position to give much assistance in such important matters as the quantity of effluent per acre that any given soil will purify. In most cases that have come under our observation, the Agricultural Authorities have utilised the effluent to the best advantage of the crops, so as to give the best financial return, without considering the quality of the effluent obtained. As long as the land available is more than sufficient, there is no objection to this procedure, for no particular plot is likely to be overworked because the effluent in this country is extremely strong, and plants do not require very large quantities of it.

(2) Discharge of effluent into the sea.

This is also a very suitable way of getting rid of septic tank effluent in places where it is possible. As in the case of distribution over land, there is usually no necessity to nitrify the effluent; it can be run into the sea without

passing it through aerobic filters. Arrangements must always be made to carry the discharge pipe well below the ebb-tide level, so that immediate dilution takes place. It is also advisable to consult the Marine Department to ascertain which way the currents flow at various stages of the monsoons. With a good effluent there is no particular necessity to pond it up and discharge it with a falling tide, but this is usually done. During the ponding-up stage contact beds can be made use of. It is perfectly obvious that a good effluent discharged into the sea can be no nuisance, whereas a crude sewage, specially if it is fresh, always contains a large amount of fœcal masses, which are apt to be washed up and deposited on the foreshore. This state of affairs is extremely insanitary and very dangerous to the public health. The discharge of sewage into the sea in the East is not complicated by such considerations as the presence of oyster beds, in any place we have heard of, though shell fish are plentiful along the sea-coast and are not infrequently eaten by Europeans.

(3) Discharge of the septic tank effluent into specially constructed tanks or ponds.

There is no doubt whatever that this is a method of disposal of septic tank effluent which has not received anything like sufficient consideration in the East. The actual quantity of septic tank effluent that has to be disposed of, is in most places, very small; this is one of the few advantages of dealing with a very concentrated sewage. The total population of the Gouripur Mill, which is one of the largest in the neighbourhood of Calcutta, is about 8,000, and the amount of sewage

that is obtained from this community is only about 50,000 gallons daily. This quantity of effluent could be run into a pond of ½ to ¾ of an acre in extent without making any appreciable difference to the appearance of the water. The work carried out at the King Institute by my assistants and myself (*vide* the Study of the Bacteriology of Drinking Water Supplies in the Tropics) demonstrates the rapidity with which a very highly polluted water is purified, due to the action of settlement and tropical sunlight. Provided the daily quantity of septic tank effluent is not too great, it is perfectly possible to put it into a small tank or pond for years together, without in any way spoiling the appearance of the pond, or giving rise to any nuisance whatever. Of course, it is understood that this particular sheet of water should be protected, and people should not be allowed to drink it. A pond of this nature should be stocked with fish, particularly the little *haplochilus*, which lives on mosquito larvæ. It is also advisable to introduce the ordinary lotus into the pond, as the growth of this kind of plant has an action in using up the nitrates in the water and they are beautiful in themselves.

The installation at Entally has been discharging its effluent into what may be legitimately described as a dirty little puddle, which is only about thirty feet in diameter and about 3 feet deep, for five years, still there has never been any nuisance arising from it, nor does it seem to have altered in appearance. There is no doubt whatever that in many places, where suitable land for irrigation purposes is not available, the discharging of septic tank effluent into a fairly large sheet of water, is one of the most sanitary ways of disposing of it.

passing it through aerobic filters. Arrangements must always be made to carry the discharge pipe well below the ebb-tide level, so that immediate dilution takes place. It is also advisable to consult the Marine Department to ascertain which way the currents flow at various stages of the monsoons. With a good effluent there is no particular necessity to pond it up and discharge it with a falling tide, but this is usually done. During the ponding-up stage contact beds can be made use of. It is perfectly obvious that a good effluent discharged into the sea can be no nuisance, whereas a crude sewage, specially if it is fresh, always contains a large amount of fœcal masses, which are apt to be washed up and deposited on the foreshore. This state of affairs is extremely insanitary and very dangerous to the public health. The discharge of sewage into the sea in the East is not complicated by such considerations as the presence of oyster beds, in any place we have heard of, though shell fish are plentiful along the sea-coast and are not infrequently eaten by Europeans.

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(4) Discharges into rivers, irrigation canals or water-courses.

From what has been said in the introductory paragraph of this chapter, it is obvious that the disposal of septic tank effluent by allowing it to run into rivers is one which is open to very serious objection. The weight of this objection varies with several factors, *viz.* (i) the quantity and quality of effluent to be discharged, (ii) the quantity of water available for rapid dilution, (iii) the number and nature of the population inhabiting the banks 10 or 20 miles below the outfall, (iv) the velocity of the current in the river and whether it is tidal or not. The connection that these bear to the problem is obvious and need not be discussed at length ; thus, it would be most unsound from a sanitary point of view, to allow a large volume of very indifferent effluent to run into a small stream, that supplied drinking-water to large villages within 10 miles of the outfall; whereas to allow a few thousand gallons of a well-nitrified effluent to pass into a huge volume of water (many of the settlements on the banks being provided with a filtered supply) would be practically free from objection. Rapid and ample dilution, the action of the tropical sun and the power that rivers undoubtedly possess of purifying themselves, all tend to the destruction of living pollution, otherwise every river in the East would be the main factor in the spread of disease. Recent researches of Houston, on the viability of Enteric organisms in the Thames water, and the work on the action of sunlight, done in the King Institute, Madras, all confirm these statements, so that due consideration should be given to these facts and the improvement of the sanitary condition of a community should not be postponed for reasons which are not really

valid. Septic tank effluent is better than crude sewage, and much of the latter finds its way into a river, if sanitary arrangements are inadequate or unsatisfactory.

It is impossible to lay down any absolute rule as to whether or not septic tank effluent should be discharged into a river or stream; as in all sewage problems, each case must be judged on its own merits. One is only able to say that from a sanitary point of view and from a study of the habits of the people in this country, the pollution of a water course may be fraught with very much more serious results than it is in Europe. Therefore, whenever possible, septic tank effluents should be otherwise disposed of. Failing any other method, the necessity for sterilising the effluent, before passing it into the stream, must be carefully considered, the whole circumstances of the case being duly examined.

(5) Using the septic tank effluent for boiler purposes.

This would be a very satisfactory way of getting rid of effluent in large mills and workshops. Unfortunately, however, it is practically impossible on account of caste prejudice; the boiler tindals and firemen would not have anything to do with the boilers, if they came to know that anything connected with sewage was used with the feed-water. It would necessitate employing sweepers in the boiler room. There is no doubt that ammoniacal septic tank liquid would be, in many places, distinctly advantageous to the millowners, as it would prevent the heavy lime scale forming the inside of the boiler. We can, therefore, only say that this method of disposal of septic tank effluent has not yet come within the bounds of practical application, on

account of the religious prejudices of the people employed in the engine room and boiler houses.

(6) Raising the effluent to boiling point by means of an apparatus placed in the flue of the boiler.

It was suggested that the effluent might be volatilized or raised to boiling point by passing it through a coil of pipes in the flue of the boilers. Certain experiments were made at Tittagarh, but they were not successful because there were some defects in the apparatus, which was made locally. The amount of pipe surface exposed to the heat was insufficient for the quantity of effluent that was passed. During the smallest flow of effluent through the pipes, the highest temperature registered was only 120° F ; this was obviously no use, and the matter has been referred to a firm of engineers in London who make a speciality in this kind of plant.

Sterilization of septic tank effluent.

From what has gone before, it is obvious that the circumstances under which it may be necessary to insist on the sterilization of septic tank effluent before it is discharged, are more numerous in India than in Europe; consequently the subject has received a lot of attention in Bengal and we give the result of our experience below.

The only method of sterilising a sewage or effluent which is both cheap and feasible is to make use of a solution of chlorine or hypochlorites, and the simplest way of preparing this is by mixing ordinary commercial chloride of lime with water. A great deal of work has recently been done on the use of chloride of lime as a

disinfectant, particularly by Dr. Schumacher (Gesundheits Ingenieur of Berlin), Proskauer, Dunbar, Rideal, Thresh and ourselves in this country. The results of all workers have shewn that it is the cheapest germicide for large quantities of fluid. The work carried out by ourselves was undertaken with a view to sterilising septic tank effluents. The conclusions arrived at were as follows :—

(*i*) that 5 grains per gallon of chloride of lime is ample to sterilise a bad effluent, and that this amount leaves a good margin for errors in adding the reagent ;

(*ii*) that 1 grain per gallon of chloride of lime is sufficient to sterilise an effluent, provided the lime contains over 30 per cent. available chlorine, that it is added in the best method, and that the effluent is a good one ;

(*iii*) that sunlight is the powerful factor in splitting up the unstable compounds of oxygen, hydrogen and chlorine ;

(*iv*) that a weak solution of chloride of lime is altered with extraordinary rapidity in the sunlight ; the stronger the solution, the less it is altered.

(*v*) that even weak solutions lose very little of their available chlorine if kept out of the sunlight ;

(*vi*) that the best method of adding chloride of lime to an effluent is to make a mixture of the powder in water and run in the liquor. For this process it is necessary to make up a strong solution 6 or 12 oz. per gallon and to keep the lid on the receptacle. One gallon of the 6 oz. solution is sufficient

for 500 gallons of effluent, and 1 gallon of the stronger solution will sterilise 1,000 gallons;

(*vii*) that a weak solution of chloride of lime is rapidly split up by the sunlight, so that free chlorine cannot be found in the river a short distance from the drainage outfall;

(*viii*) that chloride of lime kept under suitable conditions does not deteriorate so rapidly as to render the process liable to failure.

As to the best method of adding the chloride of lime liquor to the fluid to be sterilized, various kinds of apparatus have been made, all of which possess some unfortunate drawback. The method laid down in Bengal is, to make a mixture of chloride of lime and water in a wooden tub, to allow lime to settle to the bottom; the clear supernatant fluid is to be run into the effluent as it passes into a small tank. The arrangement has given a great deal of trouble, because the lime invariably blocks the tap, and it was practically impossible to keep a proper flow of the disinfectant fluid. This difficulty can be partially overcome by wrapping up the lime in a small bag made of sacking. This is put into the tub of water and stirred about; the hypochlorites dissolve rapidly in the water forming a green liquor, the lime being retained in the bag does not block up the tap. In many of the installations in Bengal a masonry tank has been provided into which the filtered effluent flows, a certain amount of liquor of chloride of lime is added and the contents are syphoned over into the discharge drains.

The good point in the use of liquor of chloride of me is, that, it is absolutely reliable and rapid in action;

in a very few minutes it will render a large volume of septic tank effluent practically sterile.

Another advantage is that it is very cheap; chloride of lime costs only Rs. 10 per cwt. landed in Calcutta; the whole of the effluent from a large mill can be sterilized for about Rs. 30 a month.

The disadvantages are that it requires a certain amount of attention. The sweepers, as a general rule, do not look after the tubs carefully and the mill engineers are too busy to do so. Improved method of adding the liquor of lime will probably be evolved, but at present the weak point in the arrangement is that it is not absolutely automatic and cannot be left entirely to itself.

The patent fluid advertised under the name of "Chloros" would probably be equally satisfactory, provided it is sufficiently cheap. We may add that there is considerable likelihood of a disinfectant being placed on the market in Calcutta, manufactured by electrolyzing a solution of common salt, as is done in Poplar, London. The use of this solution would get over the difficulty of the blocking up of the pipes with lime, and would be making use of the same reagent. It is at present somewhat doubtful as to whether the cost of this fluid will not be greater than the liquor manufactured from the chloride of lime.

No other disinfectant that we are at present aware of can compete with liquor of chloride of lime.

Case in which disinfection of effluent is necessary.

It is impossible to lay down any hard-and-fast rule as to when an effluent ought to be sterilized and when not. On broad principles it may be stated that whenever

large quantities of effluent or purified sullage are passed into a comparatively small river, which may be the drinking supply of villages not far distant, that sterilisation should be undertaken.

There is no necessity to sterilise an effluent that is passed over land, or that is run into a pond, where the natural forces bring about slow but sure purification.

There is also less necessity for sterilising an effluent if it can be discharged well away from the banks into a large river.

CHAPTER XVII.

THE MANAGEMENT AND LAYING OUT OF "TRENCHING GROUNDS."

ALTHOUGH the "trenching" of night-soil could, strictly speaking, be called a biological process, it is not usual to include it in the same category as septic tanks. These depôts, however, play such a very important part of the disposal of sewage in the tropics, that we consider it desirable to give some idea as to the best method of laying out the ground and managing these places.

It is not proposed to discuss here the arrangement for collecting and conveying the material to the trenching ground; suffice it to say that it is usual to bring it in large iron carts, hand carts or buckets. A "trenching ground" may be defined as a plot of ground in which night-soil is disposed of by burying it in the soil.

Position of Trenching Grounds.

The trenching grounds should always be situated outside a town at a distance of about $\frac{1}{4}$ to $\frac{1}{2}$ a mile from the nearest dwelling place; there is no particular object in exceeding this, the further one gets away from the town, the more expensive does the removal of night-soil become; it is necessary, however, to have the disposal

ground at a sufficient distance from an inhabited quarter, so that nuisance will not be caused. Trenching grounds should, if possible, always be on the side of the town away from the prevailing wind. It is distinctly advantageous if the ground can be separated from the town itself by a clump of bamboos, or other rapid growing tree, or a mango tope. Trenching grounds should not be placed near the banks of rivers, and it is better, if possible, to conduct the storm-water drainage of the ground on to low-lying cultivated land, than to let it pass into streams.

Character of the Soil.

Character of the soil necessary for satisfactory disposal of night-soil is of very great importance. The best soil is undoubtedly a light, fertile loam. The action of converting the organic nitrogen in human excreta into nitrates is purely bacteriological in character, being due to nitrifying organisms in the soil. These organisms are much more numerous in the upper layers of the ground than in the lower; therefore it is better to keep the excreta as near the surface as is safe from a sanitary point of view. It is also obvious that the more fertile the soil, that is to say, the more organisms it contains, the more rapid will be the action on the excreta itself.

Light sandy loam, that is occasionally found on the banks of large rivers, makes a very good soil for trenching purposes. It is absorbent, and its bacteriological activity is great.

Plots of ground composed largely of river or sea sand have been used in many places as trenching grounds. These give satisfactory results up to a certain point, but

investigation shows that the decomposition of the excreta is sometimes slow, owing to the fact that sand contains comparatively few of the common soil organism. In the Madras Presidency quite a large number of Municipalities are making use of sand with satisfactory result.

Black cotton soil makes a most excellent soil for trenching purposes as long as it is dry, when it is wet it becomes a sticky mud, and in this condition it is not very suitable. As a general rule, the districts where black cotton soil is available have a small rainfall, so that, in actual practice, this difficulty can be fairly easily overcome.

The kind of soil which gives bad results is heavy alluvial clay, when it is wet it holds too much water and when dry it forms hard clods. Furthermore in the rainy season water stands about in large quantities and may pass into drains and streams which are used as drinking supply for villages. A soil of this kind is particularly non-absorbent, the consequence is that trenching grounds situated on this formation almost invariably give rise to bad smell and nuisance. Probably the best soil for rapidly deodorising night-soil is dry black cotton soil, it is very easily powdered and is very absorbent.

Size and method of laying out of trenching grounds.

Trenching grounds should always be of sufficient size to allow of trenching of the excreta of the total population for a period of three years without using any part of the land twice. A trenching ground may be larger than this, and it is often more profitable, from an agricultural point of view, to have them very large, but the minimum size should never be less than the above.

The whole area should be divided into three equal plots. Plot No. 1 should be trenched this year, plot 2, having been trenched the previous year, should be lying fallow, and plot 3 should be under cultivation.

If the cultivation takes the form of a garden for European vegetables, a considerable portion of plot No. 2 can be utilised six months after it has been trenched.

A good pucca road leading from the town to the trenching ground, sufficiently wide to allow two carts to pass, should always be provided. This is very important and greatly increases the general efficiency of the conservancy staff. Roads, either one or two in number, according to the shape of the plots, should be constructed into each plot of ground, so as to enable the carts to come right up alongside the trenches to discharge their load. Figure XVII (*a*) shows how the roads are best laid out.

PLAN OF ROADS IN A TRENCHING GROUND.

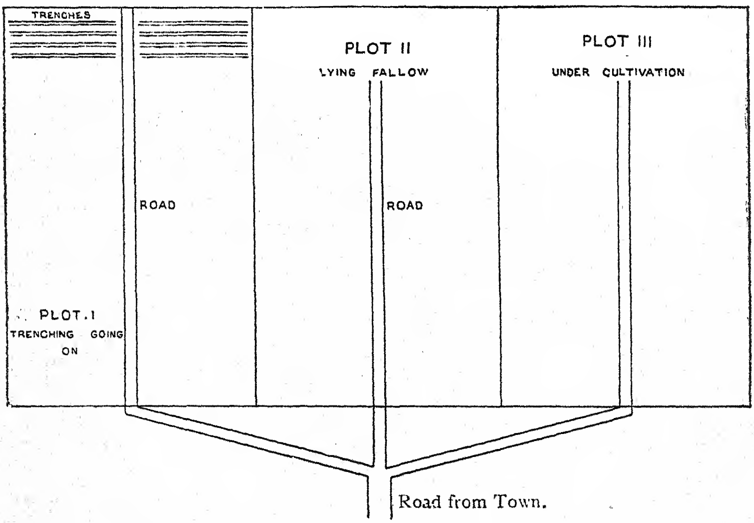


Fig. XVII (*a*).

The best dimensions for the trenches are 18 inches broad, by 12 or 18 inches deep, according to the character of the soil, the length being immaterial; they should not, however, be too long, for it necessitates filling the trenches from 2 or 3 different points; 20 to 30ft. is a very suitable working length. The trenches should be cut 24″ apart. Into these trenches only a quarter or a third of the total depth should be filled with night-soil. The orders that suit Bengal are, that in the dry weather 6 inches of night-soil may be placed in a trench 18″ deep, and 4 inches in a trench 12″ deep, in wet weather 4½ inches in an 18-inch and 3 inches in a 12-inch trench. If more than this is placed in the trenches, when the earth is filled in, the night-soil wells up and comes to the surface of the ground, causing great nuisance. As the earth is being raked into the filled trenches it should be broken up as much as possible.

A system has been in vogue in some parts of India in which night-soil is placed in trenches only about 6 inches deep, the idea of this being to keep the material as near the surface and active layers as possible. This is all very well in theory, but it is extremely bad in practice, because, with the drying action of the Indian sun and hot winds, a very highly infective dust is liable to be manufactured by this method of trenching. It is much better to bury the material at least 12 inches deep, the earth which is heaped on to the top of the excreta comes from the surface layers and is, therefore, sufficiently active for all practical purposes. Very shallow trenching can be done in private gardens, where very great care in carrying out the work is exercised and where water is abundant, but it is most unsatisfactory when left to the ordinary sweeper. Another disadvantage of shallow trenching is that it

requires a very large number of trenches for a comparatively small quantity of night-soil, hence it is more expensive than the method recommended above.

A well or tank should always be provided in the neighbourhood of trenching grounds for the dual purpose of washing the buckets and carts and irrigating a part of the ground which is under cultivation.

CULTIVATION OF THE GROUND OR DISPOSAL OF THE CONTENTS OF THE TRENCHES.

Probably the most satisfactory way of bringing the soil back to its normal condition after trenching, is, by cultivating it heavily; this should be done after a rest of twelve months. The plot should be thoroughly well dug up or ploughed deeply prior to the crops being sown. The crops that give the best result on a trenching ground are European vegetables such as cabbages, cauliflour, turnips and nohlkohl. When there is a good market for these they give the best financial return. Unfortunately, however, there is prejudice against vegetables grown on trenching grounds in some parts of the country, and not only is it extremely difficult to dispose of them, but it is with the greatest difficult that gardeners can be induced to cultivate the ground used for night-soil disposal purposes. Unless the trenching ground is a very large one and the Municipality is prepared to take up the subject in earnest, it is better to let the land to a gardener, rather than to run it departmentally; in the latter case every municipal sweeper seems to think he is entitled to the produce without payment, so no profit remains. After vegetables probably the next best crop is tobacco; a very excellent quality can be grown on trenching grounds and the yield is much in excess of

that grown in ordinary soil; ground-nut is also a satisfactory crop, so is sugarcane if water is abundant. Cereals such as barley and oats do fairly well on trenching grounds, but they are not as satisfactory as the crops already mentioned. In Eastern Bengal and Assam jute does extremely well.

In most parts of Southern India, particularly in the Madras Presidency, there is a large demand for the earth which is removed from the trenches, after the excreta have remained six to twelve months in the ground. The full trenches are sold by auction at a good price, the raiyats come with their carts, remove the earth and carry it away to manure their paddy-fields. Provided the trenches are not opened for at least six months after they have been filled, there is no possible objection on sanitary grounds to this procedure. The earth that comes out is dark in colour, resembles ordinary leaf mould in appearance, it does not give rise to any odour and may be carried in open carts without nuisance.

The method of working of trenching grounds.

This does not require any elaborate description, but a few hints may prove useful. It is always necessary to keep plenty of new trenches in hand, sufficient for three days' use in a good working limit; this is necessary because a religious festival may come round, during which time the "baildars" or diggers will not work or may be drunk.

Strict orders should be given that, as soon as the carts have discharged their load into the trenches, the excreta should be immediately covered up with earth. It is not by any means unusual for the Inspecting Officer to find that trenches half filled with excreta are

left exposed for a large number of hours. If this is done the trenching ground is always a source of nuisance and breeds large numbers of flies. Everything which delays the cartmen at the trenching ground should be avoided, as they are quite ready and willing to waste time there. Thus it is sometimes advisable to have several trenches filling at the same time.

A record of the number of cart loads per diem arriving at the ground should be kept, as the information is sometimes required and it serves as a check on the working of the cartmen.

Advantages and Disadvantages of trenching grounds.

The disadvantages of this system of disposal of night-soil are numerous. In the first place, in many parts of India, it is extremely difficult to obtain proper supervision of the working of the trenching ground ; an Overseer who is sufficiently diligent and of sufficient good caste to have any authority over the sweeper is very rare. As a general rule, the Sanitary Inspector or Overseer in charge of the trenching ground, if he happens to be a high caste man, goes there as little as possible, because he is afraid of being ostracized by his caste people ; the sweepers then cannot be trusted to carry out the work properly.

(2) The whole secret of running a trenching ground properly lies in the strict adherence to the orders given. The native sweepers' idea of exactness is very hazy. Probably the commonest error in working is that the trenches are filled much too full of night-soil. Speaking from a large experience, one almost invariably finds that the trenches are filled to the brim with a semi-fluid mass of night-soil and urine, a little earth is raked or scraped

over the top. The result is, that, the earth sinks to the bottom of the trench, and there remains a foul-smelling pool of night-soil, in which flies lay their eggs; in a very short time this becomes a mass of maggots. It is this sort of management which makes the trenching grounds such a source of nuisance; the same trenching ground with proper working might be absolutely free from odour. Nothing but the most constant supervision will ever prevent the filling of the trenches too full, because in hot weather, when the ground is very hard, it is a somewhat laborious business to cut the trenches, and naturally the coolies employed want to make the most of their labours.

(3) In Bengal and in many other parts of the country it is extremely difficult to get anybody to cultivate a trenching ground. The class of people who do market gardening work are not very numerous and not very enterprising; they fully recognise the value of night-soil on account of its manurial value, but they are afraid of being outcasted if they have anything to do with the sewage disposal depôts. In Madras, as a rule, it is less difficult to obtain cultivators for the trenching grounds.

(4) In many places suitable soil is not available; in Bengal the heavy clay does not rapidly mix with the night-soil, it is very slow to absorb the fluid part or act on the solid. In many parts of the country it is extremely difficult to arrange for supply of water at the trenching grounds; this means that the carts and buckets are not washed, and little or no cultivation can go on for want of irrigation water.

(5) In actual practice trenching grounds do breed flies and are in this way dangerous to the public health. If the management was as it should be, this should not be the case.

(6) The amount of nuisance that the trenching grounds cause depends somewhat on their size. Trenching grounds for small towns that have to dispose of night-soil of five to ten thousand individuals, particularly if other conditions are favourable, may be sanitary and devoid of any serious objection, but our experience goes to show that the larger the amount of night-soil to be disposed of, the greater the possibility of nuisance, the more the defects of the system become apparent.

(7) The whole system depends on the human being. If the men are discontented or worried, the whole organization breaks down, with most unpleasant results for the inhabitants of the town.

Advantages of this method of disposal of night-soil are unfortunately somewhat scanty. If a suitable soil is obtainable and the orders for the burial of night-soil be strictly adhered to, there is no reason why a trenching ground should be either a nuisance or a danger to the public health. It is theoretically sound to place the animal excreta in the active layers of the soil in such a way as to cause its speedy assimilation; further, it might be a profitable enterprise. Unfortunately it seems to be a physical impossibility to do this without European supervision. In Cantonments, where British non-commissioned officers supervise the trenching grounds, they are much better managed.

(8) Trenching of night-soil is supposed to be a cheap method of getting rid of the excreta from a community. Under certain ideal conditions it may be, but in by far the majority of places this advantage can be shown to be really non-existent. It is perfectly obvious that if the only available piece of ground is situated two or three miles away from the town, and if it is not above flood level, then the cost of raising the ground by

hand labour would be so great that a full septic tank installation could probably be provided, in a more convenient position, for the same money. It is not economical to have to maintain a very large staff to convey the night-soil out of the town. The feed of bullocks, replacing those that die (outbreaks of rinderpest amongst them are not unheard of), the cost of carts and the enormous wear and tear are all sources of considerable expense. Therefore, though this method of disposal of night-soil may be generally supposed to be cheap, it is frequently not economical.

To sum up the whole question, trenching of night-soil is theoretically a very sound way of disposing of it. Unfortunately, in practice, the system is usually fraught with extremely bad sanitary conditions, largely due to the lack of proper supervision, and in many places it is not an economical method.

CHAPTER XVIII.

INCINERATION OF NIGHT-SOIL.

ALTHOUGH it cannot be claimed that the incineration of night-soil is a part of the biological process, it is a method of disposal, which has been recently greatly advocated in India, so that it seems probable that some remarks on the process may be useful. To completely burn up night-soil is, of course, a sound way of disposing of it; by this means there is no possibility of contaminating a water-supply, and if arrangements are properly made, there is no danger of polluting the air by smoke or evil odour. The following conditions for the proper incineration of night-soil are absolutely essential if the method is to be a success:—

(1) European supervision.

(2) A practically inexhaustible supply of highly inflammable material such as saw-dust, wood shavings, coal-dust, etc.

(3) A properly designed incinerator.

(4) A mixing platform provided with a roof and a storage godown for the combustible material in wet weather.

If any of these four conditions are absent, the process breaks down at one time or another. It is necessary to say a few words about each of these.

First of all, European supervision is necessary because the native sweepers will never make a proper mixture of the night-soil and the inflammable material; they are always inclined to be sparing with the saw-dust or whatever is used for burning purposes. Sweepers do not know how to "fire" properly; if left to themselves, they usually put the mixture into the incinerator either too wet to burn, or too much of it at a time, so that the fire smoulders, instead of blazes, with the result that a lot of smoke is generated. The only really satisfactory incinerator we have seen was looked after by a sergeant; it was undoubtedly due to his good management that the arrangement was such a success.

(2) Inexhaustible supply of inflammable material.

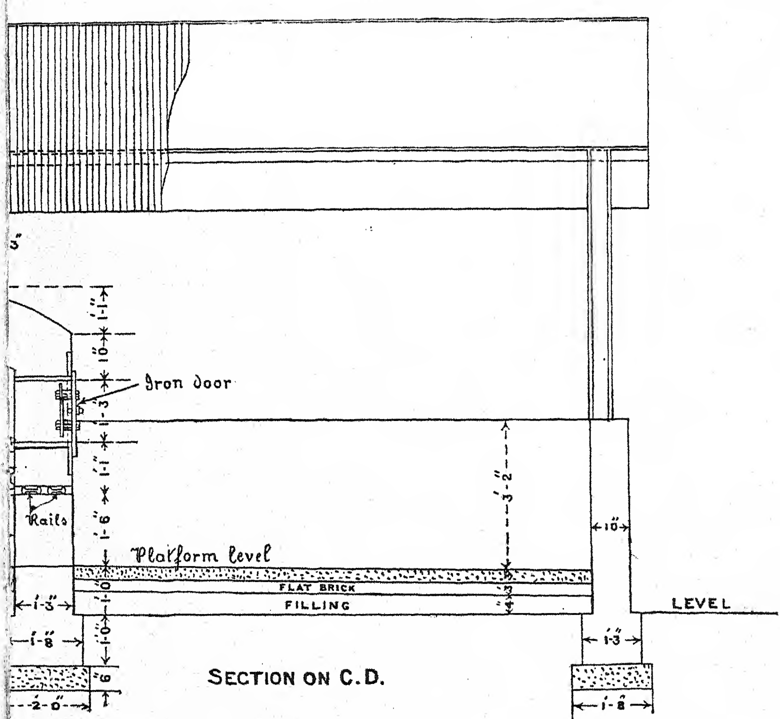
It is unnecessary to say much under this head. In order to burn night-soil a large quantity of combustible material is required, particularly if urine is to be disposed of as well. The best material is a mixture of wood shavings and saw-dust; the mixture is absorbent and readily dries up urine, and when put on to a fire which is burning brightly is readily consumed; the more of this combustible material that is mixed with the night-soil, the less is the smoke, and the less is the possibility of nuisance. Gas tar liquor from gas works is also a valuable commodity to have about an incinerator, it is highly inflammable and is a waste product which is thrown away in this country. Coal-dust is another valuable accessory though not an essential. If any of these materials have to be purchased in open market, the incineration of night-soil cannot, as a general rule, be done economically; on account of the

expense an insufficient quantity is used, the night-soil is imperfectly incinerated and the nuisance arising from the incinerator is horrible.

There is an impression abroad that street rubbish, in any part of India, is an inflammable substance. This is a serious error. The street rubbish from the towns in Bengal, Calcutta in particular, will not burn ; it requires wood or coal in order to burn it, even when put in the latest pattern incinerator. The same remark applies to rubbish obtained from the towns on the Malabar Coast. Therefore Sanitary Officers, who have recommended that night-soil and town rubbish be consumed together in an incinerator, may be making an error, for unless it has been distinctly established that the rubbish is itself inflammable, it is obviously useless to mix the two things and expect them to burn. In places like the Punjab where the rainfall is extremely small, it is quite likely that street sweepings will be highly combustible, but this should be definitely ascertained before the recommendation is made. The rubbish that is collected during the rains, in any part of the tropics, will not burn, therefore if street rubbish is to be relied on for the incineration of night-soil, a quantity of the dry material must be stored for use in wet weather ; this does not seem a very sanitary proceeding.

(3) Properly designed incinerator.

If good results are to be obtained, incinerators must be properly designed. The great mistake of the smaller types of incinerators is that the draught is not sufficient; the consequence is that a great deal of smoke, which is occasionally highly offensive, results from the process. The presence of smoke is nearly always due to two



Incinerator for burning Night-soil.

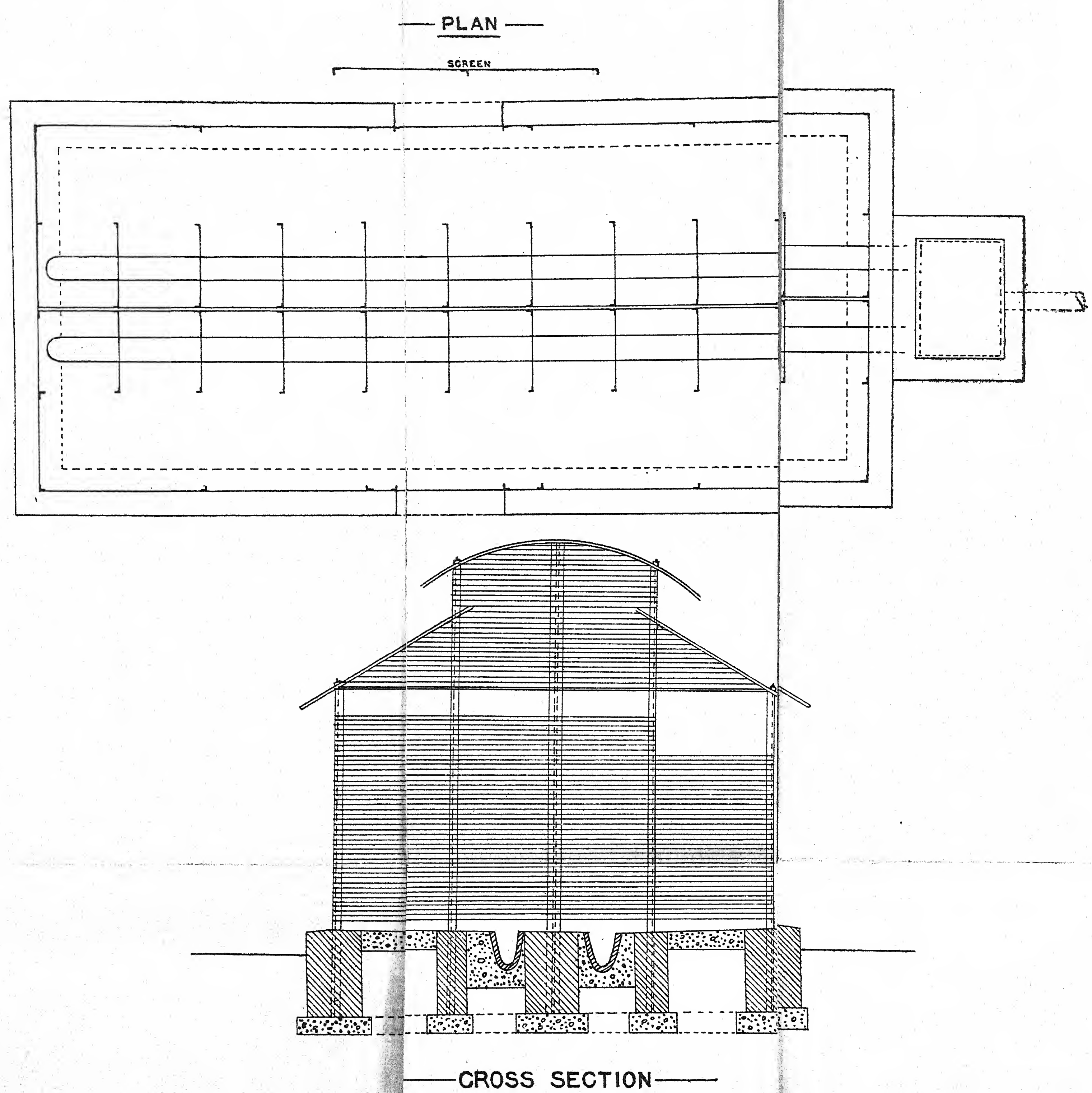


Fig. XV (*h*).—*Continued.*

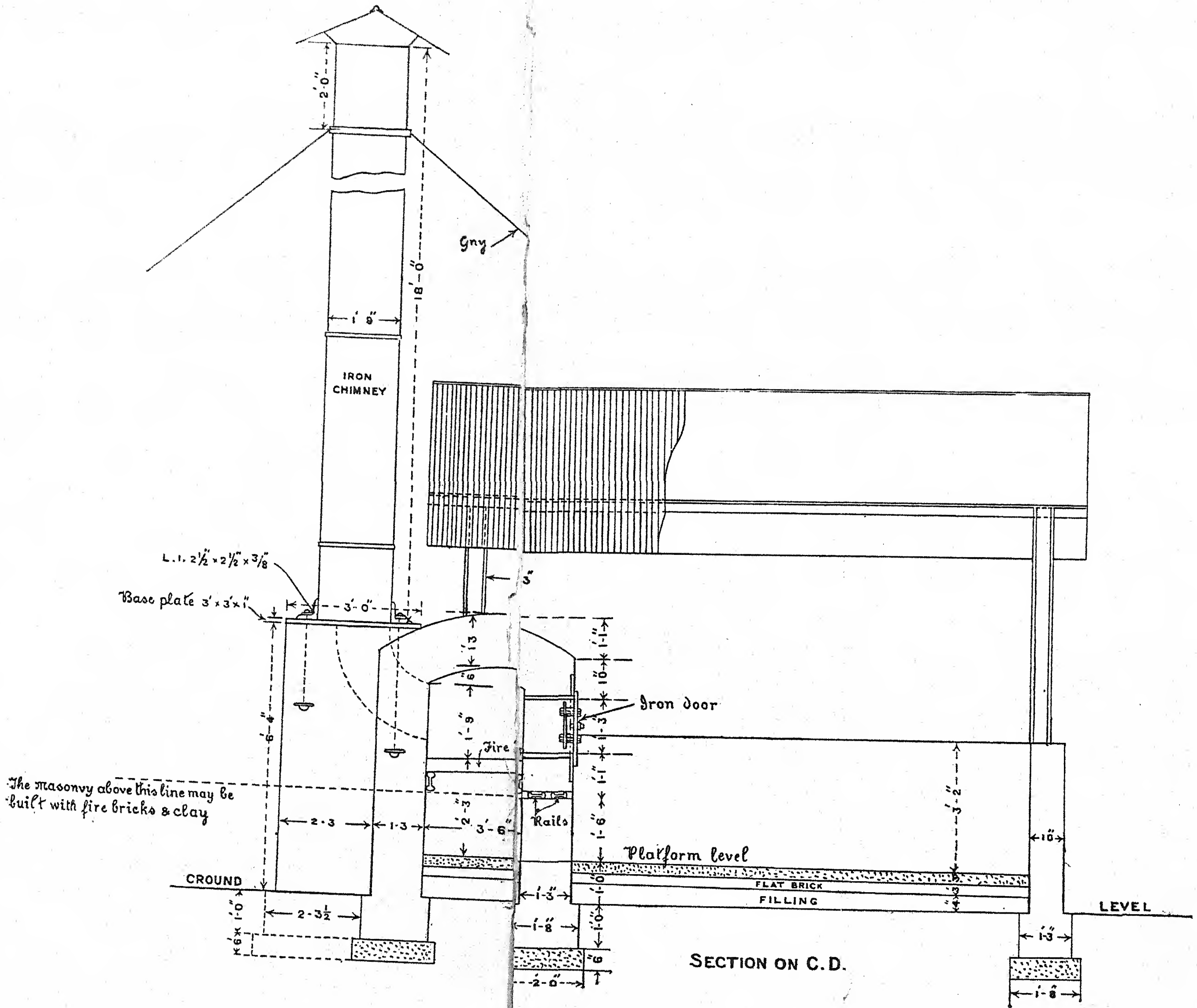


FIG. XVIII Incinerator for burning Night-soil.

SECTION ON C.D.

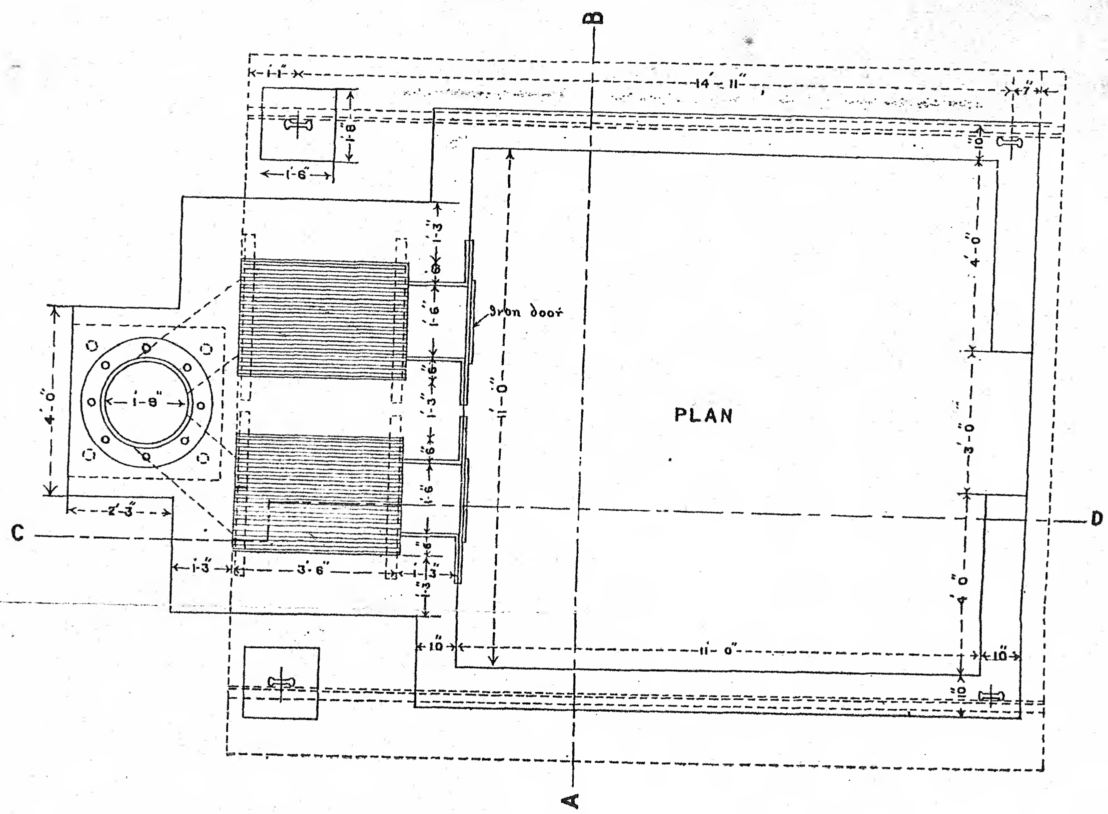
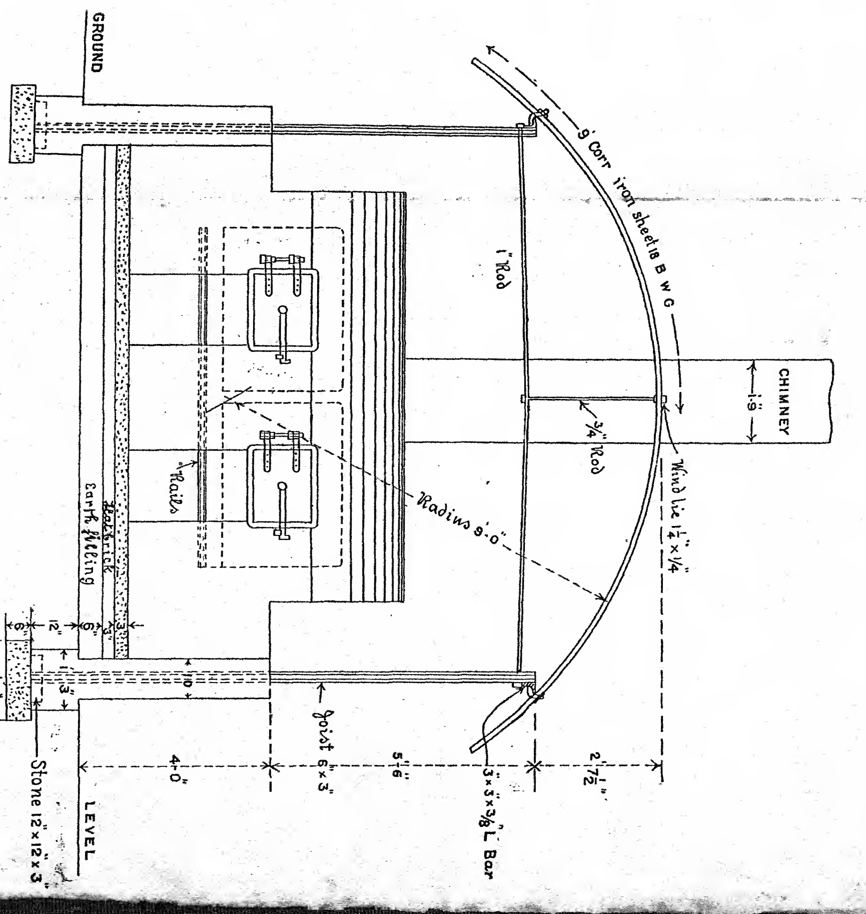


FIG. XVIII (c).



SECTION ON A.B.

FIG. XVIII (b).

things: (1) defective design of the incinerator, (2) to the proportion of dry and inflammable material in the mass to be incinerated is not sufficient. On the whole, we consider that the ordinary horizontal furnace is much more efficient for small incinerators than those fed from above. Drawing of a very good pattern, designed by a Railway Engineer on the E. I. R., is given in fig. XVIII (*a*). We have seen this type of incinerator in work and it certainly gives better results than any we have yet met with. It is somewhat expensive to erect. Our experience with the smaller vertical type of incinerators may not have been fortunate, possibly due to the unsuitable nature of the material to be consumed, but, on the whole, we are distinctly in favour of the type given in the plan, which is fed from the end, like stoking an ordinary boiler. In this particular kind of incinerator no smoke came from the chimney when large quantities of night-soil were being burnt.

(4) Mixing platform and storage godown.

In a heavy downpour of tropical rain it is impossible to keep any material, be it saw-dust, wood shavings or coal-dust, in a readily inflammable condition. Therefore it is necessary that shelters should be provided both for the mixing operation and for the storage of combustible material.

Method of working of incinerators.

Night-soil should be brought to the incinerator in small quantities, nothing larger than buckets or small hand-carts should be used. On the mixing platform a heap of wood shavings and saw-dust should be placed, the buckets of night-soil should be emptied into the

middle of this heap; the sweepers should rapidly mix the material and continue adding saw-dust if the mass shows any sign of being sodden; the heap should then be shovelled into the furnace whilst the fire is burning fiercely. A certain amount of coal or slack should be available for lighting and starting the furnace. Sweepers should be taught to trim the fire in very much the same way as boiler tenders do, and under no consideration should a large mass of material be heaped on to the fire all at once, as this is likely to give rise to quantities of smoke. With good draught and a little care in stoking there is no reason why the smoke should not be almost invisible.

It is surprising how little odour is occasioned in the process of mixing the night-soil with saw-dust and wood shavings, if this is done rapidly and if the night-soil is reasonably fresh. The odour appears to be greater if a mixture of night-soil and urine is brought to the incinerator.

We do not propose to give a lengthy description of the various failures we have seen in the course of our experience; the commonest cause of these is probably due to the supposition that rubbish of any kind is inflammable and will assist in the incineration of night-soil. Most of the failures have been the cause of indescribable nuisance and were worse, in this respect, than a badly managed trenching ground. We, therefore, recommend that when the incineration of night-soil is under consideration all conditions be carefully enquired into before the work be commenced.